MULTICRITERIA NETWORK ROUTING OF TACTICAL AIRCRAFT IN A THREAT RADAR ENVIRONMENT

THESIS

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PREFACE

The purpose of this study is to determine the efficient routes between two points along a multicriteria network. In the preliminary research for this study it was evident that multicriteria routing problems are a significant concern to a large sector of the operations research community. These types of transportation problems are exceptionally relevant to the military in determining tactical aircraft routes to designated targets under a variety of constraints. I hope this research study can add to the wealthy body of knowledge which exists on multicriteria networks.

My thanks to the Air Force Electronic Warfare Center at Kelly AFB, San Antonio, Texas and Mr. Loel Oldham whose assistance allowed me to complete this project.

I am especially indebted to my thesis advisor, Dr. Yupo Chan whose experience, insights and high standards of academic quality provided the indispensable foundation of this research project.

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ABSTRACT

Real-time route planning for tactical aircraft has established a requirement for analytical tools which prescribe optimal solutions. The Air Force Electronic Warfare Center has developed a computerized routing aid which enhances the ability to plan tactical flight missions under real-time constraints. The decision aid known as the Improved Many-on-Many (IMOM) allows the user to subjectively evaluate flight routes within enemy radar coverages. However, the mission planner is required to intuitively assesses the survivability risks associated for each user defined route. As an alternative to this method, the deterministic procedures of dynamic programming and the shortest path algorithms offer techniques which resolve optimal routes for single criteria networks. Unfortunately, the variety of independent constraints and criteria which are used to calculate satisfactory flight routes exceed the capability of conventional math programming to guarantee optimal solutions.

This research study successfully integrates the multicriteria optimization concept of generalized dynamic programming with Dijkstra's algorithm to evaluate a large scale routing network characterized by three criteria.

Based on the principle of weak mononicity, this research study demonstrates a methodology which overcomes the ineffectiveness of conventional math programming and calculates optimal paths along a multicriteria network.

In order to fully develop separate paths of ingress and egress this study also establishes the utility of implementing the Vehicle Routing Problem and the multicriteria optimization package ADBASE. This process is shown to generate all possible efficient routes from the evaluated network.

Finally, this study will demonstrate the merit of multicriteria optimization as a decision methodology used to ascertain an efficient route from a number of equally optimal alternatives without requiring a user's preference function or utility value.

This study highlights the merits of consolidating multicriteria optimization and math programming in order to provide several efficient alternative routes for the mission planner. Additionally, the invaluable effectiveness of multicriteria optimization as a decision aid is demonstrated throughout the research methodology.

Chapter 1 - Introduction

Background

The effective integration of tactical airpower in a combat environment is an essential element in current Airland Battle doctrine. This doctrine has formally addressed the synergistic effect of tactical air support within the framework of the ground tactical plan (FM 100-5;1-20). Military decision makers at all levels are currently required to address the availability and employment of tactical air support during the initial planning phases for all combat missions. As these mission requirements are generated in response to the battlefield situation, mission planners must determine feasible courses of action to support the tactical objectives. These courses of action are formulated from a wide variety of logistical and combat constraints with the foremost considerations involving the availability of tactical aircraft to match the enemy threat.

To avoid detection from enemy air defense systems, mission planners are required to develop secure routes of ingress and egress to designated targets. These routes must provide the necessary coverage from radar detection, identification and acquisition by enemy air defense systems. The active and passive techniques of radar avoidance used by tactical aircraft are critical factors in determining route

selection. The passive measures of terrain masking are used to limit exposure time of aircraft while penetrating enemy air defense networks. Active measures are also used to assist the aircraft in radar avoidance. Self-protecting electronic countermeasures and standoff jammers can temporarily limit the detection capabilities of enemy radars (Ball;1-32).

Additionally, a modern enemy air defense network presents a wide spectrum of target tracking and early warning threats to tactical aircraft. Therefore, the avoidance of radar detection is a critical element to a successful mission. The numerous combinations of threat radars against the available aircraft routes represent an extremely complex series of dependent interactions (Sterling). The difficulty in penetrating a lethal enemy radar network requires a detailed analysis of route selection. This time-consuming process has been aided by technological advancements in real-time computer simulations (AFEWC).

Current Route Planning Decision Aids The Improved Many-on-Many (IMOM) computer simulation model is presently available to all active U.S. tactical fighter wings. Developed by the Air Force Electronic Warfare Center (AFEWC) at Kelly AFB, Texas, IMOM is capable of graphically displaying the electronic order of battle, radar coverage

as affected by the digitized terrain data, jamming and air defense system envelopes. Mission planners can currently access the digitized terrain database provided by the Defense Mapping Agency (DMA) for a specific mission area. Enemy threat locations can be graphically updated in the computer simulation with an accuracy of 1.0 meters. Once the threats are incorporated into the simulation the mission planner can evaluate in real-time the radar detection parameters of various route selections. Currently, the determination of route feasibility is based on a trial and error means of evaluation (Sterling and AFEWC). IMOM presents the mission planner with the above ground level requirements to avoid radar detection. The mission planner then subjectively evaluates the feasibility of the proposed route. IMOM is a descriptive analysis tool for route selection. The operator is the integral component of the decision making process.

Future Enhancements for IMOM Based on the recommended improvements to IMOM by various users, the Air Force Electronic Warfare Center has formulated a dynamic programming (DP) based algorithm which graphically portrays a route that minimizes threat exposure. Recent evaluations at AFEWC have determined that the algorithm does not satisfy the minimal requirements of route selection (Sterling). The IMOM route optimizer doses not provide the flexibility to

avoid user determined terrain features (such as urban areas and highway systems). Also, the IMOM route will periodically enter a circular flight pattern which reduces the creditability of the program. Alternative approaches in methodology are needed to meet user requirements, including an analysis tool that provides feasible route recommendations to the decision maker. Furthermore, a methodology that provides a real-time computer assisted decision aid is essential to quick mission planning.

Problem Statement

The complexity of analyzing the numerous factors associated with route selection for tactical aircraft have created a need for real-time decision aids in mission planning. As a route analysis tool the IMOM route optimizer only partially affords decision makers a clearer evaluation of proposed courses of action.

The purpose of this study is to develop a methodology to develop the best available route to penetrate an air defense network by tactical aircraft based on the data available in IMOM. Additionally, this study will provide a multicriteria methodology to assist decision makers in selecting a satisfying route.

Scope This research is designed to provide a methodology of route analysis at the tactical level. The

geographical area used in this study will cover an area typical of most tactical aircraft missions. These include close air support (CAS), battle field interdiction (BAI) and air assault operations. The scenarios used in this study encompass the countries of Kuwait and Saudia Arabia. This methodology will be adaptable to all fixed or rotary winged tactical aircraft with missions to penetrate radar defenses.

Assumptions The assumptions in this study have many of the same limitations identified in the current field version of IMOM. IMOM assumes the worst case scenario for friendly aircraft against enemy radar air defense systems (AFEWC). These are:

1) The effects of small arms fire air defense against friendly aircraft are not modeled. The enemy radar air defense is assumed to be the primary threat in the route analysis of tactical aircraft.

2) All electronic order of battle is fully operational.

3) Ground clutter and multipath interference are not significant factors to radar detection. Human or electronic errors and vegetation or weather interference do not degrade the capability of enemy radars to correctly locate, identify and acquire friendly aircraft.

4) Radar antennas are ten feet tall.

5) Weapon system envelopes are not effected by the target aspect angles and have equal capabilities in all directions.

6) The minimum safe above ground level AGL for tactical aircraft is 300 feet (Sterling).

7) Aircraft are required to use different routes of ingress (penetration) and egress (departure).

8) The aircraft used in the research study is the UH-60 Blackhawk helicopter. The aircraft will operate at constant velocity and fuel consumption.

9) There is one staging area or starting point and three target areas. The aircraft must leave the staging area and visit all three targets before returning to the start point. This staging area is assumed to be secure.

10) Due to the relatively small size of the area used in the research study, curvature of the earth does not impact network model structures.

11) The preference function or utility value of the decision maker is not quantitatively known.

12) The generation of efficient routes is based on the data available in IMOM.

Research Objectives

This research study establishes a fundamental background in routing effectiveness. Based on these measures this study determines the least cost paths in large-scale networks based on multicriteria analysis and math programming techniques. Multicriteria analysis and the vehicle routing problem (VRP) are applied to the efficient paths to determine the optimal routes of ingress and egress. Finally, to illustrate the relative merits of each route multicriteria analysis techniques are applied to the generated set of alternatives. Specifically, the research objectives and methodology for this study include:

1. Present current information on factors associated with tactical aircraft susceptibility and vulnerability to radar detection. This material is taken

from the Electronic Warfare Center and Defense Technical Information Center.

2. List the significant measures of effectiveness for the route selection of tactical aircraft penetrating a radar air defense network.

3. Enhance the current cell-to-cell network model in IMOM with a higher resolution point-to point graph.

4. Present a methodology that determines the least cost routes for tactical aircraft based on specified measures of effectiveness, dynamic programming and multicriteria optimization.

5. Statistically, compare the efficiency of routes generated from the dynamic programming algorithm in IMOM and the research study methodology.

6. Validate the study results by comparing the routes in a large-scale point-to-point network generated from both conventional dynamic programming and the research study methodology.

Overview of Subsequent Chapters

The research literature used in developing the assumptions and methodology in this study is based on quantitative and operational disciplines. The second chapter provides the background and literature review of tactical aircraft routing effectiveness. Chapter two briefly discusses aircraft and radar performance parameters,

operational concepts, network modeling structures, current operational decision aids and routing methodologies.

Chapter three develops the methodology used in this research study. This chapter presents the development of a point-to-point network model compatible with IMOM, the integration of Dijkstra's algorithm and generalized dynamic programming and multicriteria optimization techniques used in decision analysis.

Chapter four presents the findings from applying the research methodology to three separate scenarios created in IMOM. From the routes generated in each scenario a comparison to the IMOM route optimizer and conventional dynamic programming are evaluated.

The final chapter outlines the recommendations for further studies. Additionally, recommendations to enhance the IMOM route optimizer are provided to the Air Force Electronic Warfare Center.

CHAPTER 2 - Background and Literature Review

Introduction

This chapter reviews literature pertinent to the development of a tactical aircraft routing methodology for the Improved Many-on-Many simulation model (IMOM). Specifically, the discussion covers the topics of the Improved Many-on-Many (IMOM) capabilities and limitations, measures of tactical aircraft route effectiveness, current methodologies for aircraft routing decisions, multicriteria optimization and the spacefilling curve algorithm.

The Improved Many-on-Many (IMOM) Decision Aid. IMOM was developed by the Air Force Electronic Warfare Center at Kelly AFB, Texas in response to the requirement for real-time tactical aircraft routing decision aids. IMOM is used for tactical aircraft mission planning. The program is written in VAX FORTRAN and run on a VMS based Tektronix workstation. The usefulness of IMOM in the mission planning process for tactical aircraft route selections has been demonstrated in numerous large-scale field exercises such as RED FLAG, GREEN FLAG, BLUE FLAG, COPE THUNDER, ULCHI-FOCUS LENS, TEAM SPIRIT, and CENTRAL ENTERPRISE (AFEWC). IMOM has proven to be significantly valuable in reducing the complexity of route selection under real-time constraints for tactical aircraft mission planners.

The model characteristics of IMOM are designed to

provide the mission planner with realistic data and prompt feedback necessary in selecting feasible routes for tactical aircraft. The relevant databases in IMOM used to simulate aircraft flight routes contain (TSP;3-9):

1) terrain.
2) aircraft performance measures.
3) radar performance measures.

A three dimensional surface database is used to simulate the effects of terrain masking and feasible flight altitudes. Aircraft performance envelopes and radar supported air defense capabilities are based on the most current USAF information (AFEWC). IMOM can realistically simulate any tactical aircraft in the present or near future Air Force inventory (AFEWC).

Two major radar categories are simulated in the model. These include "lookers" or early warning systems and "shooters" or radar target tracking weapon systems (TSP;3-10, 8-6). For the purpose of this research study "lookers" will be identified as passive radars and "shooters" as active radars. The exposure time and location of aircraft moving through a radar network are simulated with the information contained in the IMOM databases (TSP;3-12).

The permanent databases in IMOM provide the mission planner the ability to institute any desired scenario. The mission planner can simulate a variety of operational areas,

tactical aircraft and enemy threat situations to evaluate selected routes (TSP; 3-10). The permanent databases provide the analytical parameters used in evaluating the radar exposure time and the vulnerability characteristics associated with a given route (TSP;6-8,9). IMOM graphically displays the location along each point of the route where one or more radars detect the target aircraft (TSP;3-12).

The IMOM postprocessor provides a descriptive evaluation in the ROUTE summary file. At user specified intervals enemy radar detections along the proposed route are calculated and saved in a separate ROUTE file. The ROUTE summary file contains the following descriptive information (AFEWC):

1) aircraft true course at that position.
2) aircraft altitude at that position.
3) NATO name of the detecting radar.
4) associated air defense weapon system.
5) latitude and longitude of the detecting radar.
6) type and function of the radar.
7) clock position of the radar from the aircraft.
8) range of the radar from the aircraft.
9) altitude required for terrain masking from the detecting radar by the aircraft.

Enhancements requested by users of IMOM have included a computer-generated route selection option (AFEWC). Based on the information provided in the ROUTE summary file, mission planners are currently selecting routes primarily through a method of trial and error (Sterling). Again, the descriptive nature of IMOM output does not explicitly provide the user with the best available route.

Measures of Tactical Aircraft Route Effectiveness

The optimal routes of ingress and egress for tactical aircraft penetrating air defense networks are based on the measured effects of susceptibility, vulnerability, and survivability (Gilman;14). These factors are outlined in the form of official procedures and policies for the Air Force Survivability program. The primary purpose of the program is to ensure that "Air Force systems and mission equipment are capable of surviving the effects of man-made hostile environments" (AFR 80-38). The IMOM ROUTE summary only provides the quantitative descriptions of aircraft susceptibility to radar detection. The mission planner must assess the tactical risks associated with the probable points of detection along a given route. These subjective assessments can be applied to a route selection process for tactical aircraft by quantifying the measures of effectiveness (as the study associated with this review demonstrates).

Susceptibility is defined as "the inability of an aircraft to avoid being damaged in pursuit of its mission, to the probability of being hit" (Fundamentals;223,224). The susceptibility of an aircraft is dependent upon three major points: the scenario, the threat, and the aircraft performance measures.

The scenario is defined as the environment, flight

path and the air defense network characteristics. The threat is defined as the operational parameters of the air defense system (Fundamentals;224-226). These parameters include the detection and lethality capabilities of the enemy weapon systems. Both the scenario and the threat are incorporated into the permanent databases of IMOM (TSP;7-7,8). The flight path is the only variable completely determined by the mission planner.

The performance measures associated with aircraft susceptibility include detectable signatures or observable, electronic countermeasures, self protecting armament, and aerodynamic envelopes (Fundamentals;223-228). Aircraft detection is a function of the air defense system capabilities, the radar cross section of a given aircraft, and the flight path (Gilman 17-30). The performance capabilities of tactical aircraft and radar detection systems have been established through extensive field testing and data collection. These factors are contained in the IMOM permanent databases. The flight path of the aircraft is the critical variable that determines the degree of susceptibility in the IMOM route analysis process.

The susceptibility of an aircraft can be described as a stochastic process (Hartman;8-2,7). The probability of being hit is a function of detection, tracking and air defense weapon accuracy (Hartman 8-2,7). These factors can

be used to determine the probability of a target engagement with either Carlton's algorithm or the "cookie cutter method" (Hartman;8-12,17). Carlton's algorithm is based on a normal probability function. The probability of a hit is always nonzero. In Carlton's algorithm a specified threshold level is used to determine the engagement outcome (Hartman;8-12,17). The "cookie cutter method" uses a uniform probability function. Engagement evaluations are always binomial. A "cookie cutter method" engagement assessment results in either a hit or a miss (Hartman;8-12,17).

Vulnerability is defined as the "inability of the aircraft to withstand one or more hits by damage mechanisms, its vincibility and its liability to serious damage or destruction when hit by enemy fire" (Fundamentals;135-137). Vulnerability assessments of aircraft categories are determined by the "systematic description, delineation, and quantification of the vulnerability of the individual aircraft components" (Fundamentals;135). Vulnerability is primarily a function of the aircraft hardware and the type and proximity of impacting air defense projectiles.

There are several classifications of aircraft kills which determine vulnerability assessments (Fundamentals;136,137).

1) KK Kills: Damage that causes an aircraft to disintegrate immediately upon being hit. This is a catastrophic kill.

2) K Kills: Damage that causes an aircraft to fall out of manned control 30 seconds after being hit.
3) A Kills: Damage that causes an aircraft to fall out of control 5 minutes after being hit.
4) B Kills: Damage that causes an aircraft to fall out of manned control within 30 minutes after being hit.
5) Mission Abort Kill: Damage that prevents the successful completion of an assigned mission, but is not sufficient to cause a loss of aircraft.

IMOM does not explicitly evaluate the vulnerability of tactical aircraft. The mission planner subjectively assesses the probability of kill based on the types of radar detection evaluated along the selected route (Sterling). The route judged to have the least risk of detection provides the best defense against vulnerability. However, the vulnerability of a specified aircraft can be quantitatively determined by stochastic methods. The conditional probability of being killed given that the aircraft has been hit is formulated as a function of both the presented and vulnerable areas of the target (Fundamentals;158).

Survivability is defined as "the capability of an aircraft to avoid and/or withstand a man-made hostile environment" (Fundamentals;1,2). The probability equation

that a specific aircraft is killed can be described by:

$$P_{kill} = P_{hit} \times P_{kill|hit}$$

Therefore, the probability of survival is given as:

$$P_{survial} = 1 - P_{kill}$$

These relationships dictate that the probability of aircraft survival is maximized if vulnerability and susceptibility are reduced (Fundamentals;3,4).

The proximity of aerial routes to radar detecting air defense systems significantly affects tactical aircraft susceptibility and vulnerability. The degree of exposure to specific air defense threats can be quantitatively measured in terms of aircraft survivability (Johnson). Numerous analytical techniques are currently used to evaluate both aircraft survivability and mission accomplishment (Johnson).

Current Methodologies in Aircraft Routing Recent advances in computer technology and the transportation sciences have proven useful in determining optimal flight routes for tactical aircraft (Johnson). The application of dynamic programming and shortest path algorithms on grid-based models are currently used in evaluating tactical and strategic aircraft routes.

Hexagonal-shaped grid systems superimposed on a simulated terrain base are frequently used to model the

flight routes of tactical aircraft (Johnson). Aircraft routes designated by a hex shaped grid system simulate travel by one of two methods (Johnson). The first method is a cell-to-cell movement pattern. The flight route is simulated sequentially from the center of one cell to the center of an adjacent cell. This method provides movement in six directions with hexagonal cells and only four directions among rectangular or square cells. A cost or penalty relative to the level of threat, attrition rate, radar exposure time, and fuel consumption characterize the value of each cell along the flight route (Klincwicz;173-175).

The second method of movement is point-to-point along the arcs of the grid system network (Johnson). A cost or penalty relative to the level of threat, attrition rate, radar exposure time, and fuel consumption define each arc along the flight route (Klincwicz;173-175). Point-to-point simulations are analytically superior to other grid systems based on the capability to model aspect dependent costs and define specific routes (Johnson). The resolution of aspect dependent costs are costs which are directly proportional to the relative direction and distance between the ground observer and aerial target (Fundamentals;228-243). These costs will directly affect the probability of aircraft survival. Additionally, point-to-point models simulate

costs over specified arc lengths as opposed to the cell-to-cell model which apply the values over the entire cell area. Cell-to-cell movement actually models corridors rather than routes (Johnson). Therefore, the point-to-point method produces a higher resolution model. A graphical description of the point-to-point and cell-to-cell methods are given in figure 2-1.

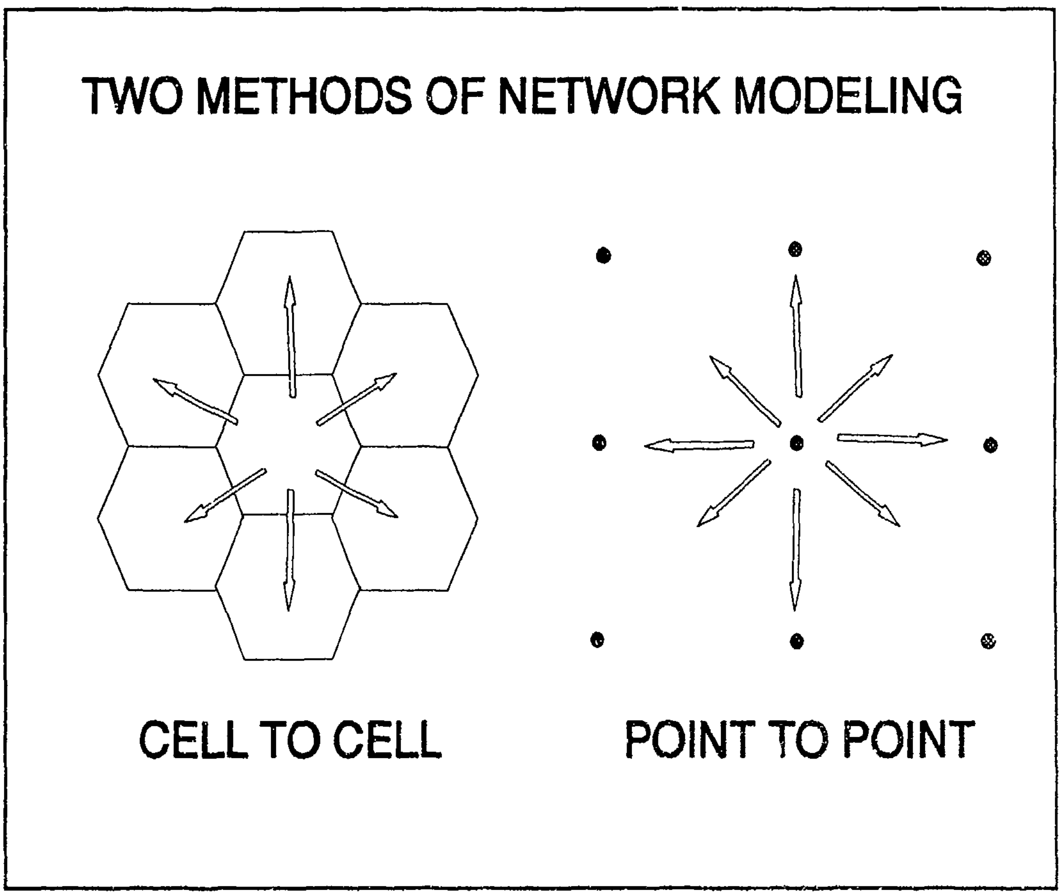

Figure 2-1 Network Representations

It should be noted that the IMOM state space uses a rectangular cell. The IMOM state space is a cell-to-cell model which simulates enemy radar coverages. The length and

width of the state space cells are defined in seconds of an arc.

Two methods widely used to evaluate the minimal cost for a route along a grid based system are dynamic programming and shortest path algorithms (Chan;21-32). Dynamic programming determines a flight route in successive stages between a user-defined origin and destination. The stages are designated as the arcs or cells of the grid based system. Each stage is evaluated for the costs incurred by movement along a given route. Costs are evaluated independent of the preceding stages. Paths are evaluated from the current stage to the destination. The least cost path is eventually determined in a recursive manner.

IMOM State Spaces and Dynamic Programming The dynamic programming algorithm used in the IMOM model is formulated as follows:

> IMOM uses a cell-to-cell grid network method to define the "area of threat coverage or the state space" (Oldham;6). Graphically, this space is defined in figure 2-2:

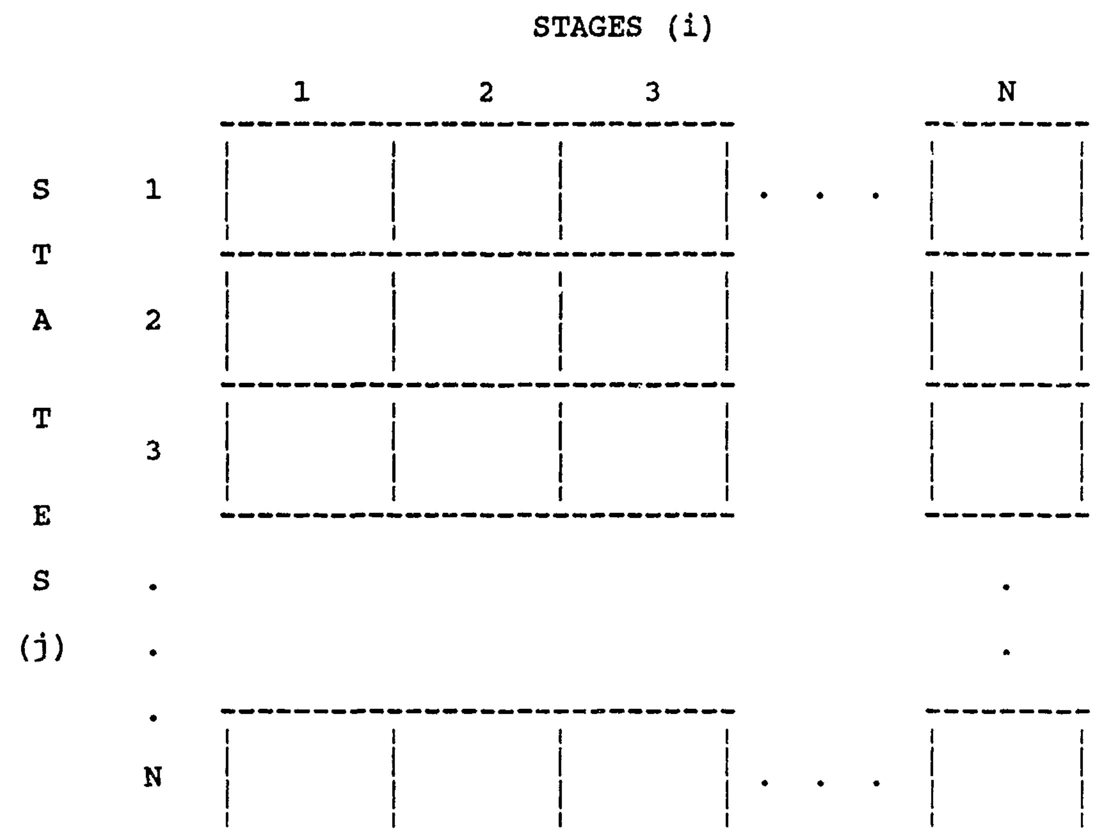

Figure 2-2 DP Representation of the IMOM State Space

Each cell contains a cost associated with severity of threat (CC_{ij}) to yield an objective function:

$$Z(x)\ a = MIN\ [E(\ CC_{ij}\ ) + MIN\ f(x)\ a]$$

where a = number of stage transition cells
b = number of state transition cells

Z(x) = Cumulative optimal return for stages 1,2,3,....,a

The sub-function f(x) is expanded for all alternative paths to determine the return function recursively and determine the least cost path.

The objective function CC_{ij} is the accumulated threat cost along the evaluated paths. The CC_{ij} function is defined as follows:

$$CC_{ij} = E(CVAL * EVAL * JVAL)$$

where,

CVAL = user assignable "base" value for each of five major classes of radar systems.

EVAL = user assignable modifier value for any specific radar or missile system.

JVAL = system assigned modifier value crediting jammer effectiveness.

Although dynamic programming is recognized as a powerful analytical tool, the computer-intensive requirements for this methodology give it limited value in route planning under real-time constraints (Johnson).

The shortest path algorithm evaluates a network to determine the least cost route. Each arc or cell is evaluated as a possible route combination between origin and destination. The combination of least cost subpaths which minimize the objective function is generated by the shortest path algorithm. This methodology is considerably less computer intensive than dynamic programming. However, most of the shortest path algorithms do not recursively account for route costs (Johnson). Given identical total route costs the most desirable path might be characterized as having a uniformly low level of threat as opposed to one with a localized high cost. However, the shortest path

algorithm will only choose the path with the overall lowest cost (Chan and Rowell;11-15).

Among the numerous shortest path algorithms, Dijkstra's method has proven to require the least computer run time for large-scale network graphs (Johnson). Additionally, Dijkstra's algorithm is based on dynamic programming techniques. This algorithm uses the principle that an optimal path must be composed of optimal subpaths (Johnson). Dijkstra's work is the basis for the Admissible Search Method or A* algorithms. These algorithms "can be expressed as a search for optimal paths in graphs of very large size" (Minoux;399).

Dijkstra's algorithm is given as follows (Goodman;294-295):

The shortest distance DIST(W) from a specified initial vertex VO to a final vertex W in a positively weighted connected network G with M vertices and N edges

which is represented by an adjacency matrix A.

```
STEP 1.   [Label all vertices]
          Label VO "determined" and label all other
          vertices "undetermined, U."

STEP 2.   [Initialize variables]
          Set DIST(U)<--A(VO,U) for all vertices U in G.

               Set DIST(VO)<--0 and
               Set NEXT<--VO.

STEP 3.   [Iterate]
          While NEXT == W do through step 5.

STEP 4.   [Update shortest distance to each
          undetermined vertex U]
          Set DIST(U)<--the smaller
          of DIST(U) and DIST(NEXT) + A(NEXT,U).

STEP 5.   [Pick a shortest distance to undetermined
          vertex]
          Let U be an undetermined vertex having the
          smallest distance DIST(U) of all undetermined
          vertices; label U "determined"; and set
          NEXT<--U.
```

In addition to the shortest path algorithms and mathematical programming, the vehicle routing problem is essential to the development of complete routes of ingress and egress. The vehicle routing problem provides the capability to assess capacity and resource constraints not directly modeled in the network (Chan and Rowell;21-23). The formulation of the vehicle routing problem is structured

as follows:

The objective function minimizes the distance cost.

$$MINIMIZE \quad \sum_{i \in I} \sum_{j \in J} \sum_{h \in H} d_{ij} \, x_{ij}^{h}$$

The first constraint ensures that the each demand point (target or objective node) is visited.

$$\sum_{i \in I} \sum_{h \in H} x_{ij}^{h} \ \{ \ |H| \ if \ j=1 \ ; \ 1 \ if \ j=2..|I| \ \}$$

Route continuity is maintained by the constraint:

$$\sum_{j \in Mp} x_{ij}^{h} \sum_{j \in Mp} x_{pj}^{h} = 0 \ \forall \ h, \ \forall \ p \in h$$

Vehicle capacity constraints are enforced.

$$\sum_{i \in I} f_i \sum_{j \in I} x_{ij}^{h} \leq V^{h}$$

Constraints are placed on the maximum flight time where t_i is the amount of time the aircraft spends at demand point i. d_{ij} is now interpreted as the "link time" from i to j.

$$\sum_{i \in I} t_i^{h} \sum_{j \in I} x_{ij}^{h} + \sum_{j \in I} \sum_{j \in I} d_{ij}^{h} \, x_{ij}^{h} \leq U^{h}$$

The next constraint ensures that aircraft availability is not exceeded at the staging area.

$$\sum_{j \in M_i} x_{ij}^{h} \leq 1 \ ; \quad \sum_{i \in M_j} x_{ij} \leq 1 \quad \forall h$$

The final constraints are the "subtour-breaking" constraints which ensure each node or set of nodes communicate with the entire network.

$$\sum_{h \in H} \sum_{i \in J} \sum_{j \in J} x_{ij}^{h} \geq 1 \ , \ J \leq I \quad \forall h$$

The methods described for route analysis have relevant operational and analytical tradeoffs associated with the requirements of tactical aircraft mission planning. Although dynamic programming provides an optimal solution for single criteria networks, the shortest path algorithms provide faster results. However, although a mathematical programming approach to the routing of tactical aircraft for single criteria will guarantee an optimal path, networks composed of multiple criterion present problems of greater difficulty.

The use of dynamic programming to determine the routing of tactical aircraft has been attempted on networks with more than one criteria (flight time, distance, fuel consumption and threat exposure). However, this technique does not guarantee an optimal solution (Carraway;95-103). To overcome this deficiency, the use of multicriteria optimization provides an alternative tool for the

examination of Pareto-optimal paths along networks with more than one criterion.

> "A Pareto optimal solution is also called an efficient, non-inferior, non-dominated or admissible solution. Pareto preference is based on the concept 'more is better' for each criterion f_i, i-1,...q; and that no other information about the tradeoff at $\{f_i\}$ is established or available" (Yu;21).

Multicriteria Optimization Multicriteria optimization has a two fold analytical relevance to the problem of routing tactical aircraft. First, multicriteria optimization techniques provide a methodology for determining the efficient paths in networks defined by more than one criterion (Carraway;95-103). The use of generalized dynamic programming as opposed to the conventional form determines the efficient path in multicriteria networks by "avoiding the violation of monotonicity" that may be experienced with conventional dynamic programming (Carraway;95).

Secondly, multicriteria optimization techniques can also be used to enumerate the routing alternatives that represent the efficient frontier or Pareto optimal solution set. Multicriteria optimization evaluates the routes as criterion vectors. In this research study the criterion vectors are defined as the distance and expected values of enemy radar detection for a given route. The multicriteria

optimization program ADBASE is capable of supporting this methodology by computing efficient extreme points (criterion vectors) for multiobjective linear constrained problems (Vehicle Routing Problem) and identifying alternative routes (Steuer;40-59). ADBASE uses the MC^2 simplex method to generate the nondominated alternative solution set. The MC^2 simplex method compares every possible combination of feasible solutions to determine the efficient extreme points. In ADBASE the range of fixed weights associated with the objective functions is essentially 0 to 1.

The techniques of math programming and multicriteria optimization are critical to the validation of alternative approaches to routing solutions. One alternative approach is the application of heuristic methods. A heuristic approach to generate near-optimal solutions represents a possible category of appealing methodologies to the tactical routing problem. Heuristic algorithms are less computer intensive than either dynamic programming or the shortest path algorithms (Bartholdi;294-296).

The Spacefilling Curve Algorithm The spacefilling curve algorithm is a heuristic approach for solving combinatorial problems in two or more dimensions.

> A spacefilling can be thought of as the limit of a sequence of recursive constructions whereby a square is subdivided into smaller squares, into which are copied scaled versions of the preceding construction (Bartholdi;293).

The spacefilling curves are mapped onto the multidimensional area of investigation which includes the points of interest (targets and staging areas in the geographical mission area). The curves are then transformed to a unit-interval of one dimension. The relative distances between the points of interest provides a trivial formulation for problems with two or more dimensions. The points of interest (enemy radar sites, airfields and preplanned ground targets) can be clustered into groups based on their proximity along the one-dimensional unit-interval. The computer resources and computational time required for spacefilling curve methodologies are minimal (Bartholdi;296). The advantage of computing solutions in near real-time provides a valuable analytical tool in tactical aircraft mission planning.

Summary

Real-time route planning for tactical aircraft has established a requirement for analytical tools that prescribe optimal solutions. The present method of trial and error with the IMOM decision aid can only provide the user with a means of subjectively evaluating alternative

routes. The mission planner must intuitively assess the survivability risks associated with each route. The development of a more quantitative means of assessing tactical aircraft routes would improve the current state of the mission planning process. However, aircraft survivability requires the representation of accurate cost functions to validate any given methodology. The deterministic methods of dynamic programming and shortest path algorithms are analytical tools that provide optimal routing solutions. Therefore, it becomes necessary to evaluate the efficient paths and routes with proven math programming techniques to determine the best feasible alternatives for the mission planner. Additionally, real-time computer requirements are necessary for the mission planning process. The category of heuristic algorithms provides an alternate methodology which accommodates the operational and analytical requirements of tactical aircraft routing.

CHAPTER 3 - Methodology

Introduction

The methodology for this study will include the analytical techniques of conventional dynamic programming (Dijkstra's Algorithm), generalized dynamic programming, multicriteria optimization (MC^2 simplex) and the vehicle routing problem (VRP). The models and programming packages used in the methodology will include IMOM (the Beta version from AFEWC which uses a route optimization program), ADBASE and a point to point grid network.

Measures of Effectiveness The measures of effectiveness used in this study will include:

1) Distance traveled between origin and destination.
2) Expected value of active enemy radar detection.
3) Expected value of passive enemy radar detection.

These measures of effectiveness will be used to define the arc weights in the grid network to determine the least cost tour that penetrates an enemy radar network. These missions can be generally described as moving through a grid network with representative terrain and threat costs. This movement originates at a source (staging area) visiting several objective nodes (targets) and returning to the source (staging area) along a specified route. The grid

network must adequately model:

1) Possible flight paths at various altitudes.
2) Three dimensional natural and man made terrain.
3) Enemy radar coverage.

The specific tour is determined by finding the least cost ingress and egress paths of specific intermediate nodes which define the path between the source node (staging area) and the objective nodes (targets). The pairwise comparison of these nodes enumerates the efficient paths which comprise a conceivably optimal route. Formulated in a matrix arrangement, these paths are defined as the cost values associated with travelling between the specified nodes. In this research study the cost can be associated with distance (the d_{ij} matrix) and the avoidance of passive and active radars (the p_{ij} and a_{ij} expected value matrices). The matrices define the costs of each criteria as a result of comparing the objective nodes and source node in a pairwise manner. By evaluating the efficient path between two specified nodes, the travel cost can be characterized as three finite criteria values. The pairwise comparison between a set of nodes would continue until every possible binary combination is exhausted. The application of multicriteria techniques and the vehicle routing problem (VRP) to the matrices generated from the grid network are used to determine the least cost route. The structure of

the VRP precludes the application of this algorithm directly to the network graph in order to determine the efficient routes. The VRP structure generates a visitation to all the nodes equated in the objective function. Although a node can be assessed a potential value of zero, the algorithm still produces a visitation to occur along the generated path. In order to avoid this circumstance the intermediate nodes and arcs along the efficient path must be determined prior to the application of the routing formulation. The choice of route is dictated by the mission planner's preference of avoiding enemy radar and minimizing explicit aircraft constraints (fuel consumption, and flight time). By generating the efficient routes and allowing the mission planner to choose a feasible route, the necessity of formulating a preference or utility function is not required.

The research study methodology is applied to three scenarios of increasing radar coverage complexity. Each succeeding scenario will simulate additional enemy radar sites to the mission area. This process demonstrates the requirement to employ automated decision aids in mission planning. Furthermore, the validity of the research methodology will be evaluated along networks of increasing intricacy.

Network Modeling

It was necessary to develop a network model compatible with the IMOM state space for this research study. A network model allows the implementation of the generalized dynamic programming methodology with the IMOM program. Additionally, the development of a network model for the IMOM state space would enhance the present capabilities of the IMOM route optimizer program.

Point-to-Point Grid Network Description The model used for this study is a two level symmetric grid network. The two levels represent upper and lower level altitudes. These network levels are measured with the mean sea level (MSL) altitudes of the research study area. Variations in distance due to the curvature of the Earth are ignored. The size of the area used in this study, approximately 1 degree latitude x 1 degree longitude, is assumed not to require enhancements for geographic curvature and radar horizon calculations. Three separate criteria network structures for each scenario are used in this study. The first network is based on distance (measured in nautical miles) and the final two are based on avoiding lexicographically ordered levels of passive and active radar detection. The nodes or vertices of each network are sequentially numbered left to right, top to bottom from the lower level to the upper level. Nodes which are not adjacently connected are given

an excessively large value to prevent unstructured path generations. A graphical description of a single level point-to-point distance criteria network cell is given in figure 3-1.

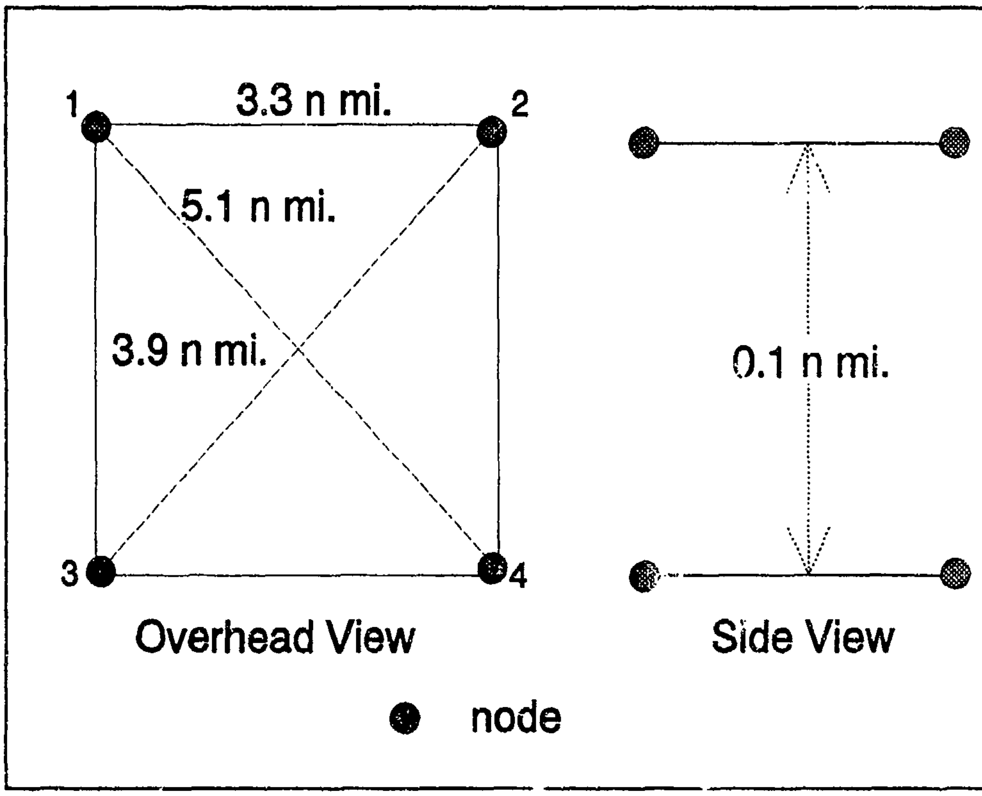

Figure 3-1 Grid Network

The three grid networks used for each scenario (one per criteria - distance, the expected value of passive radar detection and the expected value of active radar detection) weight the arcs within each graph according to the type of measurement required. The network levels are stacked directly on top of each other. A graphical description of the arcs between the two levels is given in figure 3-2. Each node in the research study network has either 3, 5 or 8

arcs connected to adjacent nodes on a different level. Movement along these arcs represents the transition to a different altitude. The network was structured as compatible to the IMOM state space cell. This created the rectangular shape grid structure oriented along the geographic lines of longitude and latitude.

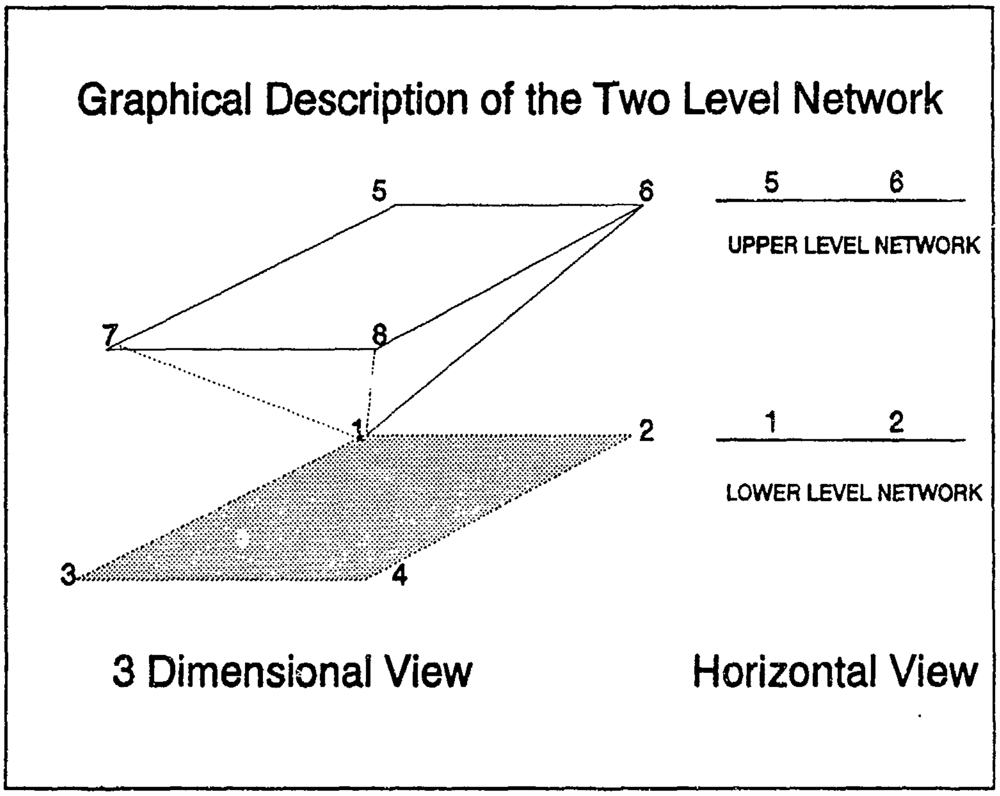

Figure 3-2 Grid Network Symmetry

Model Representation The resolution of the research model was dictated by the IMOM limitations and grid size factors. The lowest possible resolution for a state space in IMOM is 300 arc second along both the width and length of the rectangular cells. The highest resolution is 30 arc seconds. A cell size of 240 arc seconds was chosen

to minimize database construction without jeopardizing the ability to obtain realistic research results. Two major characteristics of the research study network are terrain and radar coverage modeling.

1) Terrain. The dimensionality of terrain is modeled as length, width and height. Vertices which spatially represent natural or man-made terrain are removed as intermediate nodes. The representation of natural and man-made terrain is simulated by placing an excessively large value on the arcs associated with inaccessible areas. The present form of the IMOM state space program is unable to simulate man-made features. IMOM users have requested that the route optimization option output avoid urban areas and major roads (Oliver). The application of a point-to-point network allows the simulation of these features. The scenarios used in this research study outlines two urban areas to prevent possible routing. Both cities -- Al Kuawyt and Al Jahra in the country of Kuwait are modeled into the research study network. The natural terrain is modeled along the contours of a 1:1,000,000 map.

2) Radar Coverage. Radar coverage is modeled as threat cells in the research study network. The threat cells are quantities of cost associated with a given type of radar detection level. These cells are taken directly from the IMOM state space representation. The color coded threat

cells are created in the state space program of IMOM. The IMOM state space reflects the discrete levels of active and passive radar detection by a color coded scheme. The state space also defines the cell-to-cell path of the route optimization program in IMOM. The various detection levels (color codes) are graphically interpreted by the user through the Tektronix color terminal. Based on the lexicographical rankings of the IMOM radar detection levels the probabilities of risk are calculated for this research study as follows (Oldham;8):

TABLE 3-1

COLOR CODE	THREAT DETECTION RANKINGS	PROBABILITY OF DETECTION
Yellow	Lowest 20 %	0.18
Green	Lower Middle 20 %	0.36
Blue	Middle 20 %	0.54
Pink	Upper Middle 20 %	0.72
Red	Top 20 %	0.90

The probability values are used as arc weights on both the active radar and passive radar networks. The point-to-point network was overlayed on the threat cells created by the IMOM state space. The network is situated so that nodes are placed in the center of the cell. The arcs are weighted with the value of the threat cell into which the arc is directed. Since every arc is bidirectional, the value characterizing the arc depends on the direction of movement. A graphical representation of a threat cell with seven arcs

emanating from one node is given in figure 3-3.

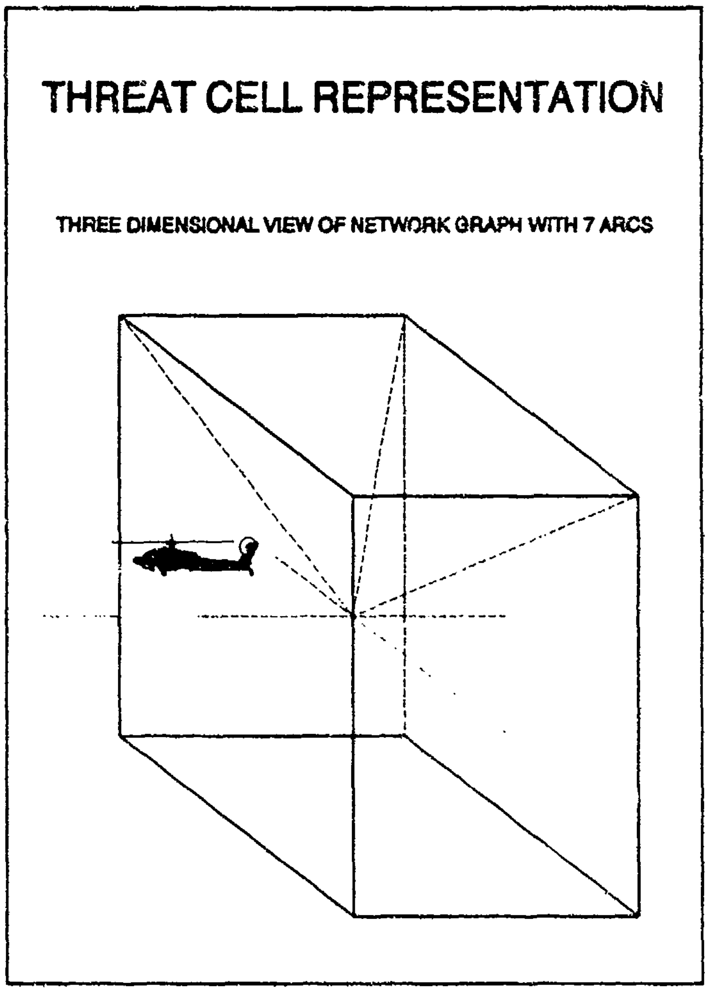

Figure 3-3 Threat Cell Representation

Model Construction A three stage manual modelling process was used to incorporate the IMOM state space graphical scenarios into the research study. In chronological order the three stages were as follows:

1) Create Tektronix prints from the scenarios created in the IMOM program. These prints reflect the different levels of radar detection, friendly and enemy airfields, enemy electronic order of battle, designated targets, urban areas and military graphics.

2) Transfer the Tektronix prints of the state space into a FORTRAN77 database. This process was accomplished by overlaying a grid network on the Tektronix print. The values for passive and active radar where manually placed into the database. The distance values used for latitude, longitude and altitude transitions are uniform throughout the grid structure. These distance values where computed with a 1:1,000,000 map and the threat cell size from the state space. The state space for two distinct altitudes were used to define the two levels in the FORTRAN77 database.

3) Recreate the efficient routes in the IMOM program. The efficient routes determined by generalized DP and ADBASE where manually placed into IMOM with the original grid overlay. These were plotted as a means of graphically interpreting the routes and validating the methodology.

The process of transferring the state space into a FORTRAN77 database is graphically represented in figures 3-4 thru 3-6.

Model Formulation

The formulation of the objective function and constraints for the generalized dynamic program utilize the aspects directly associated with the network arcs values. These values are distance, and radar detection. Other factors such as pilot error and fatigue, mechanical failures and the absence of key terrain (which might increase navigational errors) are examples of elements that cannot be directly evaluated from this network system.

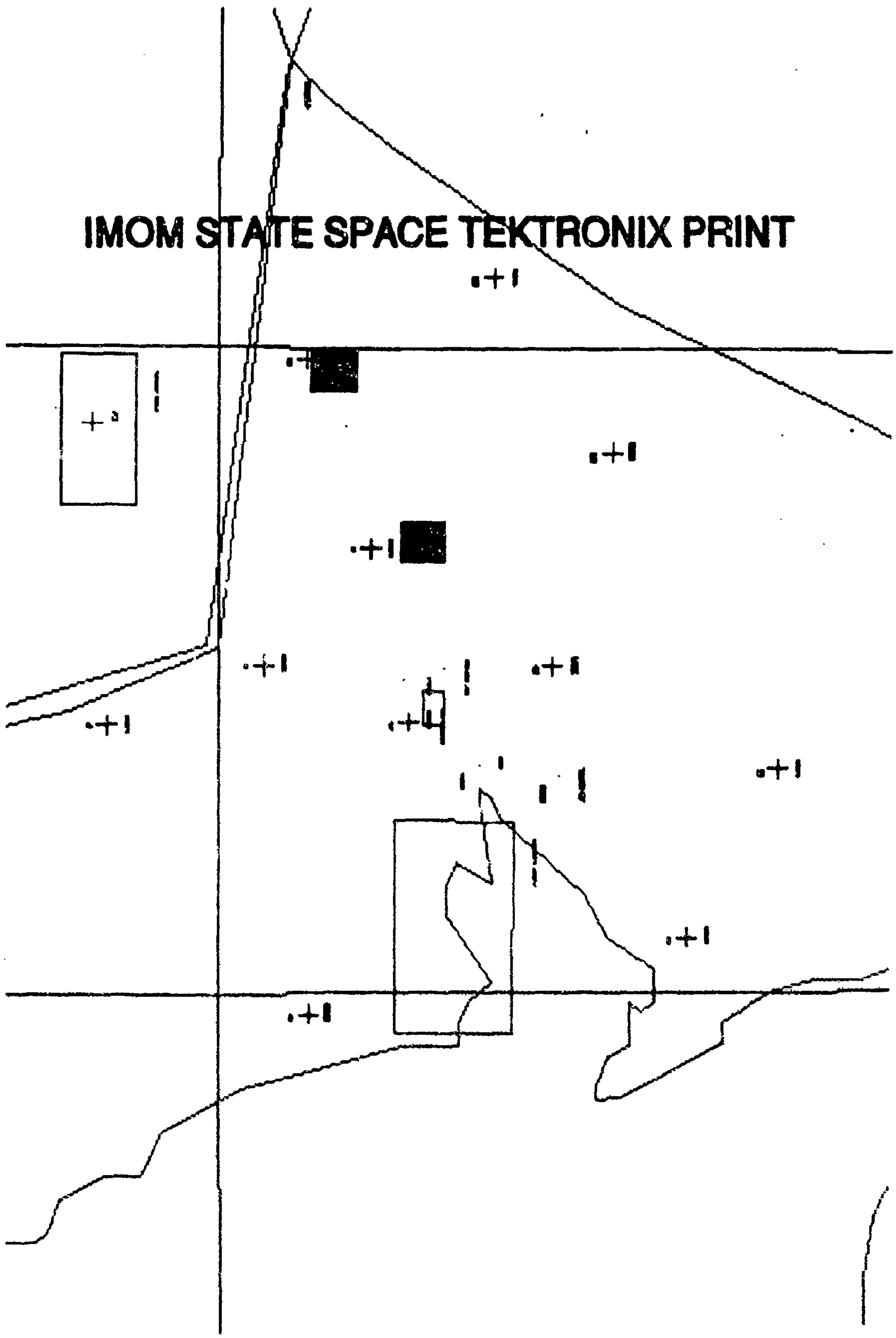

Figure 3-4 The IMOM State Space Representation

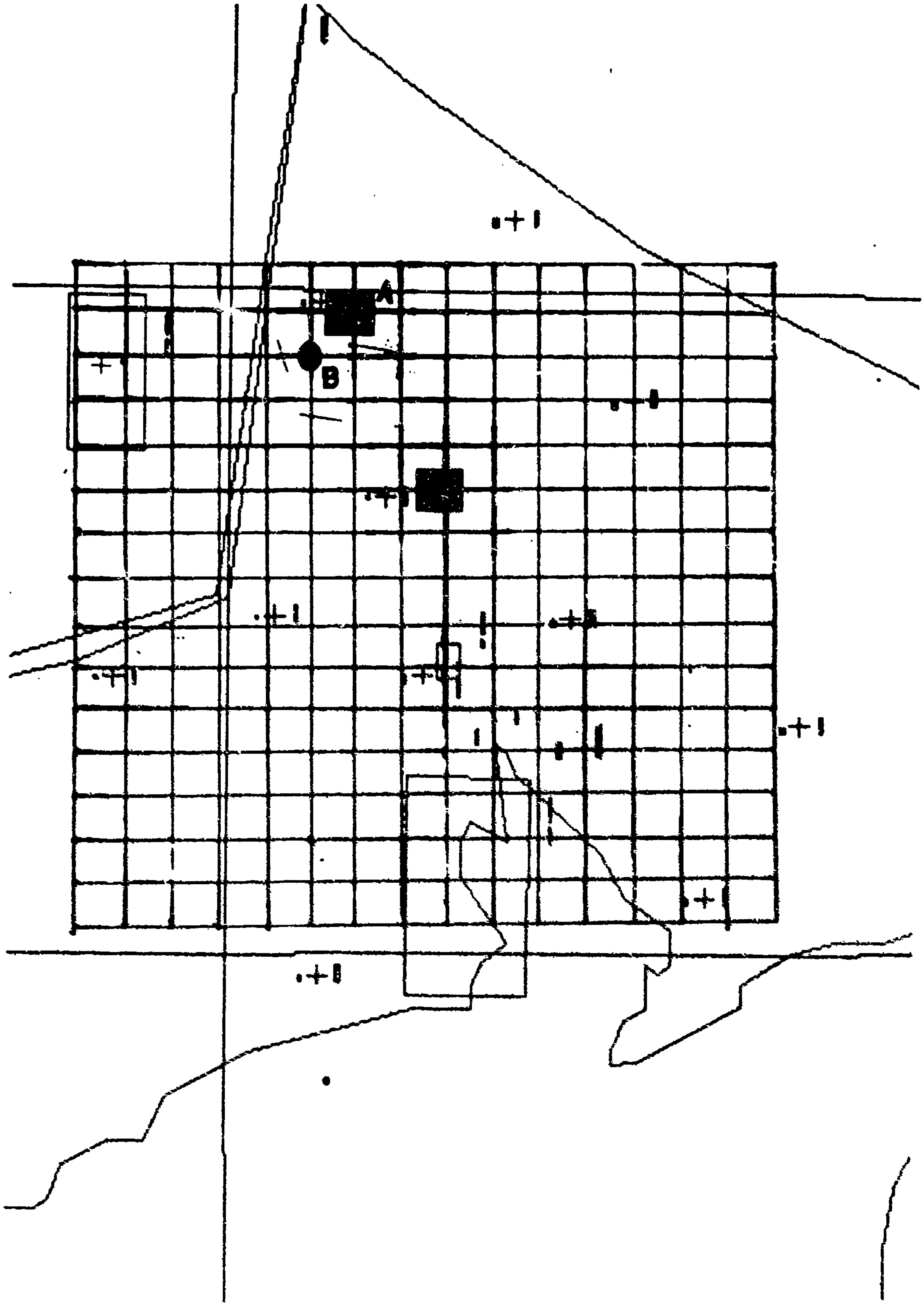

Figure 3-5 The Overlay of a Point to Point Network

on the IMOM State Space

**NODE A DATA BASE FOR ONE LEVEL
IN THE IMOM STATE SPACE**

900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
.18	.18	.18	900	900	900	900	900	900	900	900	900	900	900	900	900
.18	900	.18	900	900	900	900	900	900	900	900	900	900	900	900	900
.18	.18	.18	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900

**NODE B DATA BASE FOR ONE LEVEL
IN THE IMOM STATE SPACE**

900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	.90	.18	0.0	900	900	900	900	900	900	900	900	900	900	900	900
900	.18	900	0.0	900	900	900	900	900	900	900	900	900	900	900	900
900	0.0	0.0	0.0	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900

The value of 900 is used to create an arc value large enough to simulate inaccessible or infeasible paths.

Figure 3-6 FORTRAN representation of the IMOM State Space.

The research study objective function used in the generalized dynamic programming extension of Dijkstra's algorithm is an additive form. Since the individual criteria were assumed to be independent, the objective function was not formulated as a multiplicative function. However, unlike the objective function the individual criteria are either additive or multiplicative. The distance criterion is an additive function. The passive and active radar probabilities are multiplicative. Since the network is not a uniform distance from any given point, as in a parallelogram, the radar detection probabilities were multiplied by the associated arc distance. These produce expected values of detection. For example, given two arcs with identical probabilities of detection the arc with a greater distance will have a larger expected value. This mathematical formulation was necessary in order to represent the discrepancies in radar exposure. It is assumed that aircraft velocity, radar cross section and aspect angles are constant throughout the flight. The exposure to radar is modeled as solely a function of distance travelled and the radar detection probability for each network arc. By multiplying probability of detection and the distance traveled, the generalized objective function calculates the active and passive radar detection levels as expected

values. The three criteria are modeled as follows:

$$f(Distance) = \sum_{i=1}^{j} DISTANCE$$

$$f(Active) = \sum_{i=1}^{j} ACTIVE\ RADAR_i$$

$$f(Passive) = \sum_{i=1}^{j} PASSIVE\ RADAR_i$$

where,

The efficient path is defined by arcs i thru j.

$DISTANCE_i$ = The distance in nautical miles along arc i.

$ACTIVE\ RADAR_i$ = The probability of active radar detection along arc i times the distance travelled along arc i.

$PASSIVE\ RADAR_i$ = The probability of passive radar detection along arc i time the distance travelled along arc i.

Generalized Dynamic Programming From the objective function described above the following least cost paths are determined:

1) The source node (staging area) to each of the objective nodes (target).
2) Between each of the objective nodes.
3) From each objective node to the source node.

These paths will be determined without traveling along the same intermediate nodes in order not to duplicate any portion of the ingress and egress routes. A distance (d_{ij}) and two expected value (p_{ij} and a_{ij}) matrices are constructed from the general dynamic programming results.

These matrices represent the distance and risk expected values associated with traveling between the staging area and the targets. The d_{ij}, p_{ij} and a_{ij} matrices are determined by using nine normalized sets of fixed weights (λ_i) associated with each of the three performance measures for the objective function of the generalized dynamic program:

$$MINIMIZE\ \lambda_1 * f(Distance) + \lambda_2 * f(Passive) + \lambda_3 * f(Active)$$

where,

$$(\lambda_1; \lambda_2; \lambda_3) =$$

(1,0,0) (0,1,0) (0,0,1) (.333,.333,.333)

(.25,.25,.5) (.25,.5,.25) (.5,.25,.25)

(.375,.375,.25) (.375,.25,.375) (.25,.375,.375)

In order to determine the efficient paths along a large-scale network the principles of Weak Optimality and generalized dynamic programming as discussed by Carraway are used in Dijkstra's algorithm (Carraway;95-103).

The general DP objective function is evaluated from a specified initial vertex VO (staging area) to a final vertex W (target) in a positively weighted connected multicriteria network G with M vertices and N edges. G is actually an

aggregated graph composed of the three criteria networks; A (distance), B (passive risk) and C (active risk).

STEP 1. [Label all vertices]
Label VO "determined" and label all other vertices "undetermined, U."

STEP 2. [Initialize variables]
Set DIST(U)<-- λ_1A(VO,U) + λ_2B(VO,I) * A(VO,I) + λ_3C(VO,I) * A(VO,I)
for all vertices U in G.

Set DIST(VO)<--0 and
Set NEXT<--VO.

STEP 3. [Iterate]
While NEXT $\neq$ W do through step 5.

STEP 4. [Update least cost distance to each undetermined vertex U]
Set DIST(U)<--the smaller of DIST(U) and DIST(NEXT) + λ_1A(NEXT,U) + λ_2B(NEXT,U) * A(NEXT,U) + λ_3C(NEXT,U) * A(NEXT,U)

STEP 5. [Pick an efficient path to an undetermined vertex]
Let U be an undetermined vertex having the smallest cost for each undetermined vertices in each of the adjacent networks (A,B,C); label U "determined"; and set NEXT<--U. The smallest cost is determined by finding the minimum extrema from each determined vertex to the terminal node W through the undetermined node U along the evaluated path.

Construction of The Distance and Detection Level Matrices The construction of the matrices will be accomplished by finding the least cost paths (both ingress and egress) from the source node to the objective nodes. The matrices are computed from pairwise comparisons between VO (staging area) and W (three target) nodes. The possible

combination of paths between two nodes is artificially reduced under specific conditions. Nodes are removed for the following reasons:

1) Terrain representation which prohibits realistic routing or mission planning overflights.
2) Prevention of a egress path which duplicates an intermediate node on an ingress route.
3) Prevention of overflying one target enroute to a succeeding target area.

ADBASE and The Vehicle Routing Formulation The vehicle routing formulation is applied to the d_{ij}, p_{ij} and a_{ij} matrices to determine the least-cost tour. The risk and distance matrices generated by each set of fixed weights (λ_i) are used to formulate the objective functions for use in ADBASE. The objective functions are:

$$MIN\ f(distance) = \lambda_1\ f(d_{ij})$$
$$MIN\ f(passive\ detection) = \lambda_2\ f(p_{ij})$$
$$MIN\ f(active\ detection) = \lambda_3\ f(a_{ij})$$

This objective function is subject to the vehicle routing constraints. Formulation of the resource constraint is developed from the aircraft characteristics and capabilities. A UH-60 Blackhawk helicopter is used as the aircraft in this study. The unclassified characteristics of the UH-60 are given in table 3-2 (FM 90-4;1-3).

TABLE 3-2
UH-60 CHARACTERISTICS

Passenger capacity	11 - 14 Personnel
Useful Load	9266 lbs.
Internal Fuel Capacity	1450 lbs. / 224 gals.
Normal Cruising Speed	100 knots
Endurance at Cruising Speed	2.3 hours
Fuel Consumption per Hour	840 lbs. / 130 gals.

From the aircraft characteristics the maximum allowable distance for one lift is conservatively estimated as

$$\sum\sum d_{ij}\, x_{ij} \le U$$

where, U equals 140 nautical miles.

The distance constraint of 140 nautical miles was chosen to discriminate between routes which require the UH-60 to make a refueling stop before completing two lifts.

ADBASE will determine the efficient set of routes for each group of distance and expected value of detection objective functions (Steuer;390-396). Utilizing the MC^2 simplex option in the ADBASE program allows the complete evaluation of every possible λ_i combination.

<u>Filtering the Nondominated Criterion Vectors</u> The FILTER subprogram of ADBASE is used to eliminate dominant routing alternatives. The routes generated from the distinct sets of distance and risk matrices are defined by criterion vectors with three elements; distance, and the expected values of passive and active radar detection. However, the efficiency of these criterion vectors must be evaluated against routes generated by all other matrix sets. Although a specific criterion vector can be efficient for a fixed λ_i set, it may represent a dominated alternative when compared to the criterion vectors from other matrix sets. The FILTER subprogram eliminates dominated criterion vectors (alternative route) to identify the efficient subset (Steuer;11-21). Therefore, a pairwise comparison of each criteria in the FILTER program is used to screen the efficient routes and determine the nondominated subset.

<u>Forward and Reverse Filtering</u> Forward and reverse filtering processes are also available in the FILTER subprogram. The use of additional filtering by these methods assist the decision maker in reducing the number of possible alternatives to a desirable set of acceptable choices. The forward and reverse filtering process is

described as follows (Steuer;390-396):

1) Given a set of nondominated alternatives forward filtering determines the widest dispersed set of criterion vectors. The user set number of dispersed criterion vectors is determined by the weighted L_p metric distance measure:

$$\| v^t - v^h \|_p^\pi = [\sum_{i=1}^{q} (\pi_i |v_i^t - v_i^h|)^p]^{1/p}$$

where,

q is the length of the vector being filtered.

π_i is the range equalization weight associated with the i th component of the vector being filtered.

p is the metric parameter, $p \in [(1,2...) \cup (\infty)]$.

2) Once the dispersed set of criterion vectors is determined the decision maker chooses a preferred alternative. This alternative is used as a seed value in the reverse filtering process. Alternatives closest to the seed value are selected using the L_p metric equation.

3) Step 2 is repeated until the decision maker is satisfied with a preferred alternative.

A graphical example of this process is given in figure 3-7. The dispersed set of nondominated alternatives is presented in 3-7a. From this set the decision maker chooses #26 as the preferred alternative. As a seed value in reverse filtering #26 produces the set given in 3-7b. From this set the decision maker chooses #14 which produces the reverse filtered set in 3-7c. Finally, the decision maker chooses #9 which produces the reverse filtered set in 3-7d. From this set the decision maker decides upon #28.

This example graphically illustrates the "sequence of progressively smaller neighborhoods" which provides a preferred solution from a reduced set of alternatives (Steuer;396).

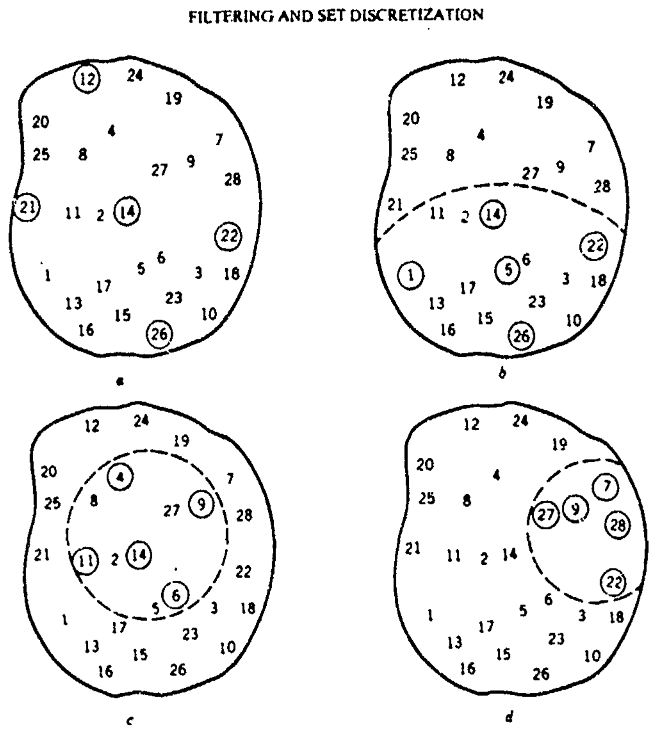

Figure 3-7 Forward and Reverse Filtering

Plot the Nondominated Criterion Vectors The criterion vectors from the ADBASE output are used to determine the efficient frontier of nondominated solutions (routes). These routes represent the best alternative routes available to the mission planner based on the expected values of detection and total distance travelled. Two possible methods for plotting nondominated routes are demonstrated. The first is to plot the criterion vectors of the efficient routes in a three dimensional space. The

second method is to plot the nondominated routes as two criteria from the three that are available (distance, passive and active expected values). Depicting criterion vectors in two dimensional space provides a more comprehendible illustration of the alternative routes to the decision maker.

Comparison to IMOM Generated Routes The paths generated by the IMOM route optimizer and the research methodology are statistically compared according to the relative measures of distance and exposure to passive and active radars. Furthermore, the IMOM-generated routes will be compared to the efficient frontier of nondominated alternatives determined by the ADBASE program.

Example Problem A simplified example problem demonstrates the following:

1) The benefit of optimizing a path with generalized dynamic programming in comparison to conventional methods.

2) The proposed methodology effectiveness on a smaller-scale network with multiple criteria.

3) Highlight any possible deficiencies associated with the proposed methodology.

Replication of Carraway's Calculations The example network used in this example is borrowed from Carraway's article "Generalized Dynamic Programming for Multicriteria Optimization", European Journal of Operations

Research, January 1990. The network is a six node asymmetric direct graph. Carraway presents a two criteria optimization problem to find the maximum objective function valued path from node 1 to node 6. The graph is depicted with the associated criteria in figure 3-8.

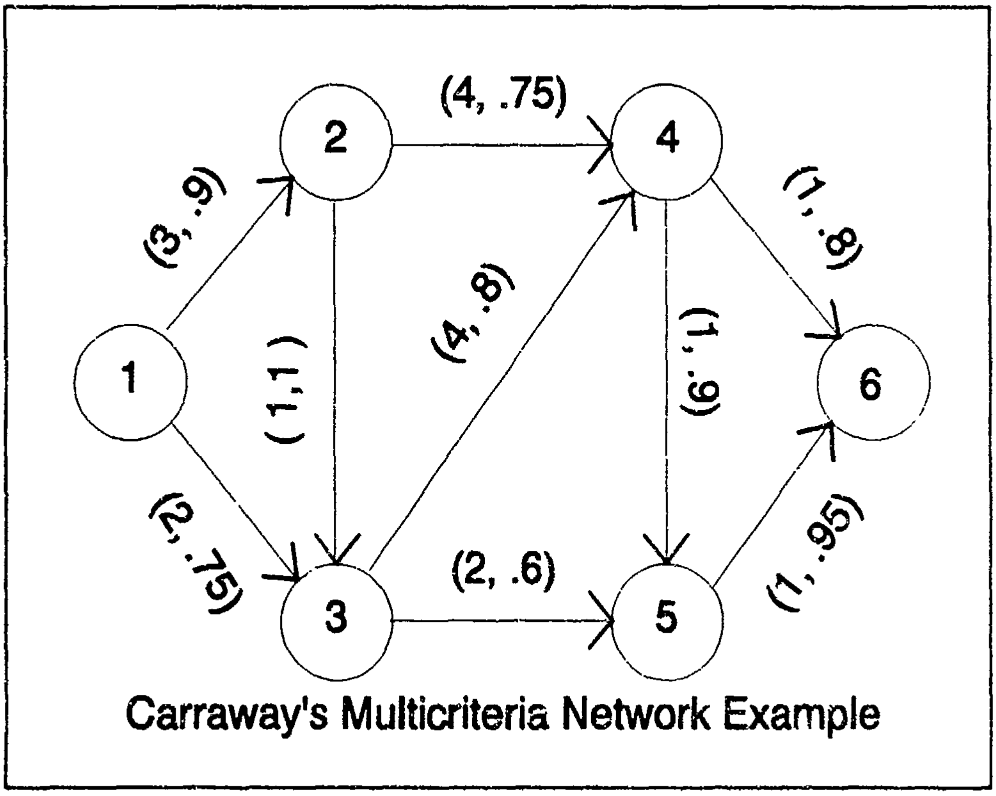

Figure 3-8 Carraway's Multicriteria Network.

The objective function chosen randomly by Carraway for maximization is

MAXIMIZE: u(d,p) = - Distance + 20 x Reliability

For each arc value in figure 3-7 distance is given as the first criteria and reliability is the second. In this example the distance criteria values are additive and the reliability criteria are series multiplicative. Carraway

notes that if all the network criteria and the functional form of the objective function are either multiplicative or additive then conventional dynamic programming will produce an optimal solution (Carraway;98-99). However, the combination of these functional forms in networks of more than one criterion will not guarantee optimality due to the requirement for a strictly monotonically increasing or decreasing objective value (Carraway;99). Strict mononicity in conventional DP evaluates a possibly optimal subpath based solely on the accumulated values of the determined nodes and the measured cost of travel to any adjacent nodes. The results of Carraway's analysis between conventional and generalized dynamic programming are given in table 3-3 (Carraway;102).

TABLE 3-3
GENERALIZED AND CONVENTIONAL DYNAMIC PROGRAMMING
RESULTS FROM CARRAWAY'S NETWORK EXAMPLE

Node j	Efficient path pairs (d,p) to node j	Preference func. values u(d,p)	Conventional DP f(j)	u(f)	i*	Generalized DP f(j)	u(f)	i*
1	(0,0)	0	(0,0)	0	-	(0,0)	0	-
2	(3,.9)	15	(3,.9)	15	1	(3,.9)	15	1
3	(2,.75) (4,.9)	13 14	(4,.9)	14	2	(2,.75)	13	1
4	(6,.6) (7,.675)	6 6.5	(7,.675)	6.5	2	(6,.6)	6	3
5	(4,.45) (6,.54)	5 4.8	(6,.54)	4.8	3	(4,.54)	5	3
6	(5,.4275) (7,.513)	3.55 3.26	(7,.513)	3.26	5	(5,.427)	3.55	5

The use of Dijkstra's algorithm to function as both a generalized and conventional dynamic program is demonstrated by replicating Carraway's results. The computer programs along with the database where written in FORTRAN77 and are provided in appendices 1 and 2. The generated results are provided in table 3-4.

TABLE 3-4
GENERALIZED AND CONVENTIONAL DYNAMIC PROGRAMMING
RESULTS FROM AN EXTENSION OF DIJKSTRA'S ALGORITHM

Conventional DP results:

FROM NODE	1	TO	2	WITH TOTAL u(d,p)	VALUE	15.00
FROM NODE	2	TO	3	WITH TOTAL u(d,p)	VALUE	14.00
FROM NODE	2	TO	4	WITH TOTAL u(d,p)	VALUE	6.50
FROM NODE	3	TO	5	WITH TOTAL u(d,p)	VALUE	4.80
FROM NODE	5	TO	6	WITH TOTAL u(d,p)	VALUE	3.26

THE TOTAL COMPUTING TIME IS	0.06
THE TOTAL DISTANCE VALUE IS	7.00
THE TOTAL RELIABILITY VALUE IS	0.513

Generalized DP results:

FROM NODE	1	TO	2	WITH TOTAL u(d,p)	VALUE	15.00
FROM NODE	1	TO	3	WITH TOTAL u(d,p)	VALUE	13.00
FROM NODE	3	TO	5	WITH TOTAL u(d,p)	VALUE	5.00
FROM NODE	3	TO	4	WITH TOTAL u(d,p)	VALUE	6.00
FROM NODE	5	TO	6	WITH TOTAL u(d,p)	VALUE	3.55

THE TOTAL COMPUTING TIME IS	0.04
THE TOTAL DISTANCE VALUE IS	5.00
THE TOTAL RELIABILITY VALUE IS	0.4275

The conventional DP efficient path is determined as nodes 1 - 2 - 3 - 5 - 6 with a final objective value of 3.26. The generalized DP path of 1 - 3 - 5 - 6 with an objective function value of 3.55 is superior. The successful replication of Carraway's results with the generalized DP extension of Dijkstra's algorithm is a necessary validation of the research formulation.

To continue the validation process of the research formulation, the application of generalized dynamic programming with Dijkstra's algorithm is also applicable

for intermediate nodes. The results provided in tables 3-5 and 3-6 indicate that the generalized DP extension of Dijkstra's algorithm for intermediate nodes along the same network remains valid.

TABLE 3-5
CONVENTIONAL DYNAMIC PROGRAMMING
RESULTS FROM AN EXTENSION OF DIJKSTRA'S ALGORITHM
(INTERMEDIATE NODES)

```
FROM NODE  2  TO  3  WITH TOTAL u(d,p) VALUE        19.00
FROM NODE  2  TO  4  WITH TOTAL u(d,p) VALUE        11.00
FROM NODE  3  TO  5  WITH TOTAL u(d,p) VALUE         9.00
FROM NODE  5  TO  6  WITH TOTAL u(d,p) VALUE         7.40

         THE TOTAL COMPUTING TIME IS        0.02
         THE TOTAL DISTANCE VALUE IS        4.00
         THE TOTAL RELIABILITY VALUE IS     0.57

FROM NODE  3  TO  4  WITH TOTAL u(d,p) VALUE        12.00
FROM NODE  3  TO  5  WITH TOTAL u(d,p) VALUE        10.00
FROM NODE  5  TO  6  WITH TOTAL u(d,p) VALUE         8.40

         THE TOTAL COMPUTING TIME IS        0.02
         THE TOTAL DISTANCE VALUE IS        3.00
         THE TOTAL RELIABILITY VALUE IS     0.57

FROM NODE  4  TO  6  WITH TOTAL u(d,p) VALUE        15.00

         THE TOTAL COMPUTING TIME IS        0.02
         THE TOTAL DISTANCE VALUE IS        1.00
         THE TOTAL RELIABILITY VALUE IS     0.80

FROM NODE  5  TO  6  WITH TOTAL u(d,p) VALUE        18.00

         THE TOTAL COMPUTING TIME IS        0.02
         THE TOTAL DISTANCE VALUE IS        1.00
         THE TOTAL RELIABILITY VALUE IS     0.95
```

TABLE 3-6
GENERALIZED DYNAMIC PROGRAMMING
RESULTS FROM AN EXTENSION OF DIJKSTRA'S ALGORITHM
(INTERMEDIATE NODES)

FROM NODE	2	TO	3	WITH TOTAL u(d,p) VALUE		19.00
FROM NODE	2	TO	4	WITH TOTAL u(d,p) VALUE		11.00
FROM NODE	3	TO	5	WITH TOTAL u(d,p) VALUE		9.00
FROM NODE	5	TO	6	WITH TOTAL u(d,p) VALUE		7.40
				THE TOTAL COMPUTING TIME IS	0.04	
				THE TOTAL DISTANCE VALUE IS	4.00	
				THE TOTAL RELIABILITY VALUE IS	0.57	
FROM NODE	3	TO	4	WITH TOTAL u(d,p) VALUE		19.00
FROM NODE	3	TO	5	WITH TOTAL u(d,p) VALUE		9.00
FROM NODE	5	TO	6	WITH TOTAL u(d,p) VALUE		8.40
				THE TOTAL COMPUTING TIME IS	0.04	
				THE TOTAL DISTANCE VALUE IS	3.00	
				THE TOTAL RELIABILITY VALUE IS	0.57	
FROM NODE	4	TO	6	WITH TOTAL u(d,p) VALUE		15.00
				THE TOTAL COMPUTING TIME IS	0.04	
				THE TOTAL DISTANCE VALUE IS	1.00	
				THE TOTAL RELIABILITY VALUE IS	0.80	
FROM NODE	5	TO	6	WITH TOTAL u(d,p) VALUE		18.00
				THE TOTAL COMPUTING TIME IS	0.04	
				THE TOTAL DISTANCE VALUE IS	1.00	
				THE TOTAL RELIABILITY VALUE IS	0.90	

The results for both terminal and intermediate nodes indicates the high degree of effectiveness demonstrated by generalized dynamic programming and possible applications to large-scale networks. In every case there exists only one efficient route for the selected objective function to be maximized. Additionally, the generalized DP extension of Dijkstra's algorithm provides an opportunity to reduce the

maximum number of required calculations and computer time in determining the efficient path along a multicriteria large-scale network. The comparative summary of the generalized and conventional DP results for intermediate nodes is given in table 3-7.

TABLE 3-7
COMPARISON OF GENERALIZED AND CONVENTIONAL DP RESULTS

ORIGIN TO DESTINATION NODE	OBJECTIVE FUNCTION VALUE CONVENTIONAL	GENERALIZED
1 TO 6	3.26	3.55
2 TO 6	7.40	7.40
3 TO 6	8.40	8.40
4 TO 6	15.00	15.00
5 TO 6	18.00	18.00

Application of Proposed Methodology to the Example Problem The example network used to replicate Carraway's results will be enhanced to provide a greater similarity to the actual research problem. Carraway's network is altered to a symmetrical multicriteria graph. Additionally, the objective function is changed to the following functional form:

$$MINIMIZE\ u(d,p) = \lambda_1 * distance + \lambda_2 * reliability$$

where,

$$[\lambda_1, \lambda_2] = [(1,0), (0,1), (.5,.5), (.25,.75), (.75,.25)].$$

As in the previous problem, distance and reliability are respectively additive and multiplicative. The initial

stage of the problem is to determine by pairwise comparison the efficient paths between nodes 1, 4 and 5 for each set of λ_i (*where* $i = 1, 2$) values. The generalized DP extension of Dijkstra's algorithm is used to generate these paths. Each efficient path determines two distinct matrices. The first matrix defines the distance d_{ij} values and the second matrix the r_{ij} reliability values. The matrices are used as the objective functions for the ADBASE program to find the efficient routes from the efficient paths. This methodology is intended to take advantage of the optimality theorem which states that an efficient path is composed of efficient subpaths (Carraway;98-99). An extension of this theorem would logically presume that an efficient route is composed of the efficient paths which delineate the d_{ij} and r_{ij} matrices. Using these matrices as the coefficients for a multiobjective vehicle routing problem, ADBASE generates the efficient routes. After evaluating the example network with the generalized DP extension of Dijkstra's algorithm, the pairwise comparisons of the specified nodes (1, 4 and 5) for tne five sets of λ_i values revealed only one efficient set of paths. It should be noted that for this particular problem the egress path was not limited by the ingress path. The relatively small size of the example network prevented the removal of intermediate nodes on the ingress path from

the egress calculations. The matrices computed by the generalized DP extension of Dijkstra's algorithm for the five sets of λ_i values are given in table 3-8.

TABLE 3-8
DISTANCE AND RELIABILITY MATRICES
RESULTS FROM AN EXTENSION OF DIJKSTRA'S ALGORITHM

DISTANCE

NODES	1	4	5
1		1.0	4.0
4	1.0		7.0
5	4.0	7.0	

RELIABILITY

NODES	1	4	5
1		.600	.450
4	.600		.900
5	.450	.900	

ADBASE determined the efficient routes from the matrices generated by the generalized DP extension of Dijkstra's algorithm.

To validate the methodology of generating efficient paths with a finite set of fixed weights, the ADBASE program was used to determine efficient routes for all possible combinations of path sets.

TABLE 3-9
THE COMPARISON OF ADBASE AND
GENERALIZED DP / ADBASE GENERATED ROUTES

	GENERALIZED DP	CONVENTIONAL DP
EFFICIENT ROUTE	1-3-5-4-3-1 1-3-4-5-3-1	1-3-5-4-3-1 1-3-4-5-3-1
TOTAL RELIABILITY	.243	.243
TOTAL DISTANCE	11	11

The replication of efficient routes by the ADBASE program validates the methodology proposed in this research study. However, it is noted that the effectiveness of using fixed weights to determine all possible efficient paths is dependent upon the resolution and scale of λ_i values. It is possible to miss a number of efficient paths in a larger and more complex graph with a finite of number weighted values. The size and complexity of the network will directly impact the relative effectiveness of the given sets of weights used to determine the efficient paths. The combinatorial effect on the number of efficient paths in a larger network would require a lower resolution of λ values. The fact that fixed weights do not guarantee the generation of all possible efficient paths indicate the possibility of missing several or all the nondominated routes. However, this example problem does indicate that for the efficient paths

that are determined by fixed weights, nondominated routes for the generated path sets can be identified by implementing ADBASE.

Summary The methodology for this study is summarized in figure 3-9.

RESEARCH STUDY METHODOLOGY

SCENARIO GENERATION

Generate a scenario with IMOM.

Develop an Electronic Order of Battle.

Designate a staging area and targerts.

MODEL CONSTRUCTION

Develop a point to point multilevel network.

Model man made and natural terrain features.

Model radar coverages and distance with arc weights.

Transfer the IMOM scenario and point to point network to a FORTRAN77 data base.

DETERMINE EFFICIENT PATHS

Generate efficient paths between the staging area node and the target nodes using Generalized DP.

DETERMINE EFFICIENT ROUTES

Determine the efficient routes from the efficient paths using ADBASE and the vehicle routing problem (VRP).

PRESENT ALTERNATIVE ROUTES

METHOD 1: Use the FILTER program to interactively determine the best alternative with the decision maker's input.

METHOD 2: Plot the alternative routes as a function of two criteria. The decision maker chooses an alternative based on the plotted routes.

Figure 3-9 Research Study Methodology

Chapter - 3 Analysis and Results

MODELING

Model Construction As described in chapter three the completion of transferring the IMOM state space terrain and radar coverage is a three step process. The entire process of transferring the state space was exceedingly time consuming and therefore, a number of limitations were imposed on the research. These limitations restricted the size and scale of the point-to-point network representation of the mission area. The database for radar coverage and terrain was manually entered with a user-interactive option of the generalized DP computer program. The inclusion of a higher resolution network was beyond the scope of this research. Given these limitations, the development of the FORTRAN77 database still required a large amount of memory storage capacity. Each scenario required approximately 6 to 7.5 megabytes of memory storage. The excessive scale of the network representations was created by the FORTRAN77 matrix format used in the research study. Although the basic network for each scenario were composed of only 512 nodes, each of the three criteria represented a separate graph with differing arc values. All three networks for each separate scenario was composed of a total 1536 nodes and 786,432 arcs.

Model Representation The resolution of the research model was dictated by the limitations of both IMOM and a reasonable grid scale. The lowest possible resolution for a state space in IMOM is 300 arc second cells and the highest is 30 arc-seconds. A cell size of 240 arc seconds was chosen as the maximum level of resolution to obtain realistic research results. Additionally, a higher resolution would require a significant increase in the memory storage and database construction. For example, a 60 arc-second cell would require 3721 nodes per criteria network or a total of 11163 nodes and 415,375,523 arcs. The three-step process to enter this size graph into a FORTRAN77 database was limited by the time available to conduct this research. The application of an automated process to enter the IMOM cell-to-cell state space scenario from the tektronix terminal to a FORTRAN77 point-to-point representative database was beyond the scope of this research study. The grid network used to overlay the Tektronix state space prints is 16 nodes long by 16 nodes wide. The cell symmetry is described in chapter three. The representation of natural and man made terrain is simulated by placing a excessively large value on the arcs associated with inaccessible areas. As described in chapter 3 the contours of the area used for this research were modeled in both levels of the criteria networks. Additionally, the

cities of Al Kuwayt and Al Jahar were also eliminated as possible intermediate nodes along any possible efficient paths.

The process of manually plotting the radar detection probabilities and distance from the Tektronix prints to the FORTRAN77 database introduces a degree of possible measurement error. The ability to completely eliminate these possible sources of error with a high degree of confidence were beyond the scope of this research.

Scenario Development

This research used three distinct scenarios to determine the efficiency of generalized dynamic programming and ADBASE in route selection. Each of the scenarios encompasses the country of Kuwait and the southern border along Saudia Arabia. The tactical planning mission for each of the three scenarios was to determine the nondominated routes that visit three target areas in Kuwait from a single staging area along the international border in Saudia Arabia. The starting location and the three targets were identical for all three scenarios. The aircraft used in this research study was the UH-60 Blackhawk.

The electronic order of battle for each of the scenarios was comprised of active and passive radar. The density of active radar detection coverage increased with each succeeding scenario. The increasing density of

electronic activity for each scenario was used to demonstrate the requirement for computer-assisted decision aids in the routing of tactical aircraft once the complexity of the tactical situation increased.

The data obtained for the active and passive radar sites was unclassified. The ranges and functional characteristics where made available by the Air Force Electronic Warfare Center.

The weapon system characteristics used in this research study are given in table 4-1 (IMOM;EOB File).

TABLE 4-1
WEAPON SYSTEM CHARACTERISTICS

NAME	TYPE	MAXIMUM WEAPON SYSTEM RANGES ALTITUDE (feet)	GROUND RANGE (nm)
SAM 3	Surface to Air	0 - 99	0.0
		100	29.7
		101 - 1200	29.7
		1201 - 16000	29.7
		16001 - 35000	29.5
SAM 4	Surface to Air	0 - 249	0.0
		250	6.5
		251 - 1500	9.2
		1501 - 25000	10.3
		25001 - 35000	5.9
SAM 5	Surface to Air	0 - 49	0.0
		50	20.0
		51 - 1900	21.1
		1901 - 11000	20.5
		11001 - 15000	18.9
		15001 - 19000	17.3
GUN 1	AAA	0	0.0
		1 - 500	1.6
		501 - 1000	2.2
		1001 - 11000	2.7
		11000 - 35000	0.0
FAR VIEW	Early Warning	MAX unambiguous range:	270
		MAX scope limit:	190

The locations of the staging area (origin node), targets (destination nodes), and military markers are given in table 4-2 and graphically depicted in figure 4-1.

The passive radar (early warning) coverage are common to each of the three scenarios. The passive radar remains unaltered for each succeeding scenario. A graphical

representation of this coverage is given in figures 4-2 and 4-3.

TABLE 4-2
SPECIAL MILITARY LOCATIONS AND DESCRIPTIONS

NAME	DESCRIPTION	LOCATION LATITUDE/LONGITUDE	NETWORK NODE NUMBER
101st DIV	Unit area conducting air assault	vic 103960N 169239	vic 483
PZ	Pick up Zone Staging Area	vic 103960N 169239E	483
Kuwait City	Restricted overflight	vic 105953N 171850E	vic 125 381
Al Jahra	Restricted overflight	vic 105480N 171120E	121 377
MSR	Target inside Kuwait	292148N 473587E	106
Salem Airfield	Target inside Kuwait	292148N 472345E	104
Command & Control	Target inside Kuwait	292855N 473363E	74

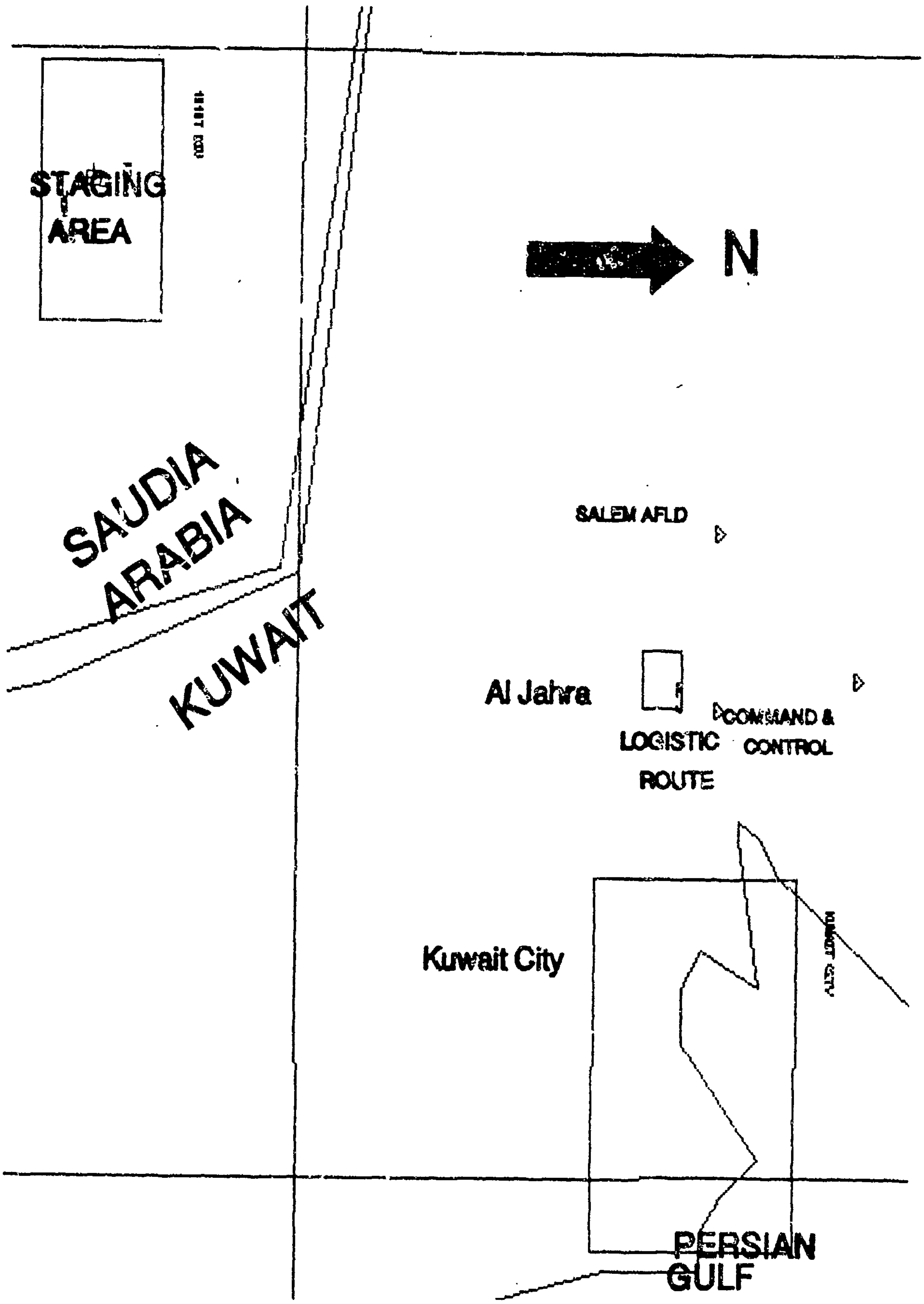

Figure 4-1 Research Study Area - Persian Gulf

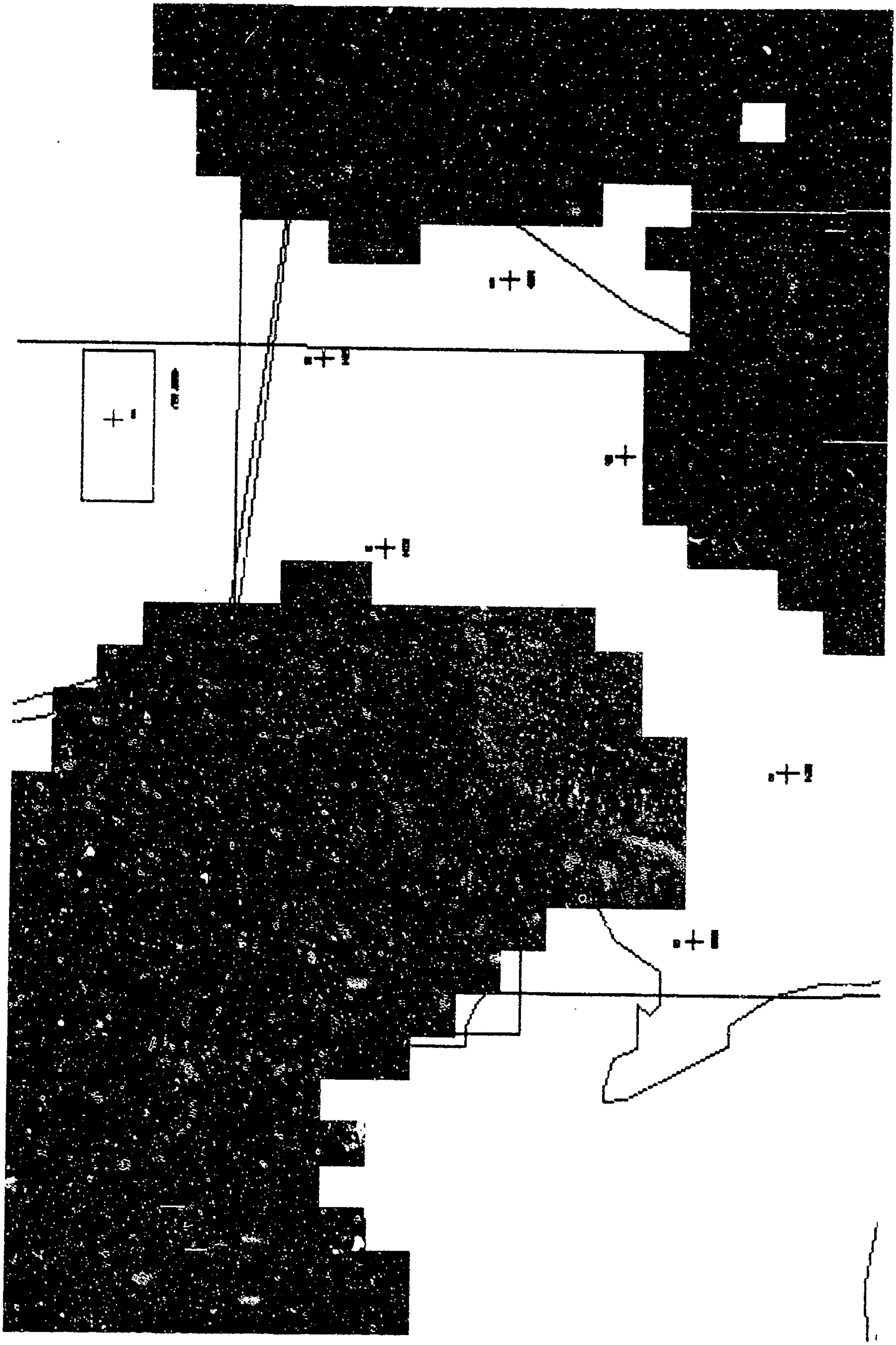

Figure 4-2 Lower Level Passive Radar Coverage of the IMOM State Space

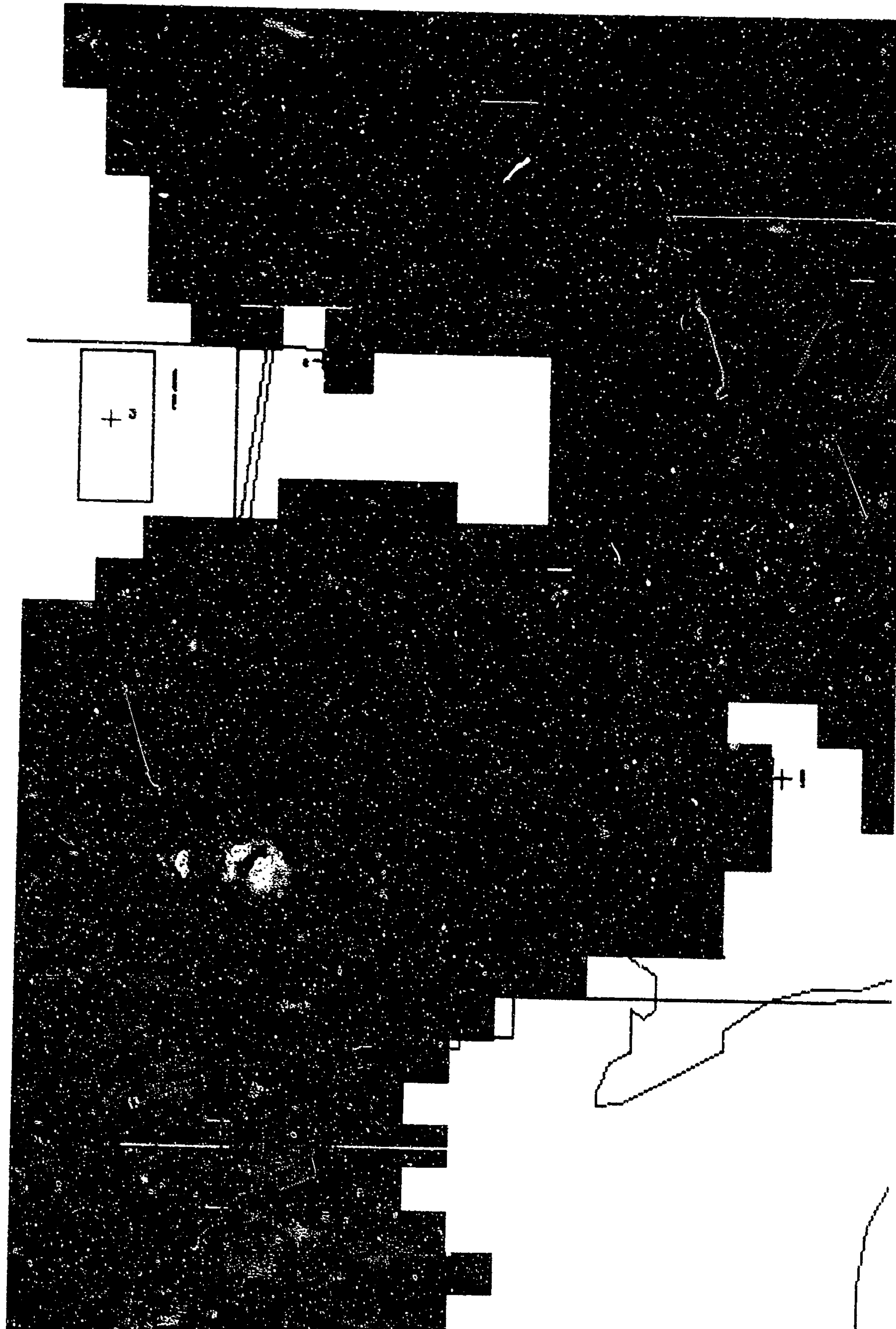

Figure 4-3 Upper Level Passive Radar Coverage of the IMOM State Space

Scenario One The active radar (target tracking systems) coverage for the first scenario is shown in figures 4-4 and 4-5. The state spaces in both figures represent the lower and upper level radar coverages respectively. The weapon systems and locations of the electronic order of battle for the first scenario are given in table 4-3.

TABLE 4-3
SCENARIO 1 ELECTRONIC ORDER OF BATTLE

WEAPON SYSTEM	NUMBER OF SYSTEMS	LOCATION LATITUDE	LONGITUDE
FAR VIEW	3	291556N	461634E
		300537N	465614E
		285542N	480327E
GUN 1	5	285013N	473512E
		290401N	472940E
		290740N	472940E
		291321N	471846E
		294856N	473921E

The results of the generalized dynamic program for the nine sets of λ_i values are given in appendix 3. These results represent the pairwise comparisons of the target nodes and staging area node. The pairwise comparisons determine the distance, expected passive and active radar detection values. The vehicle routing problem was solved using the ADBASE program. The pairwise generated sets of matrices were used to formulate the objective function coefficients. The formulation of the vehicle routing

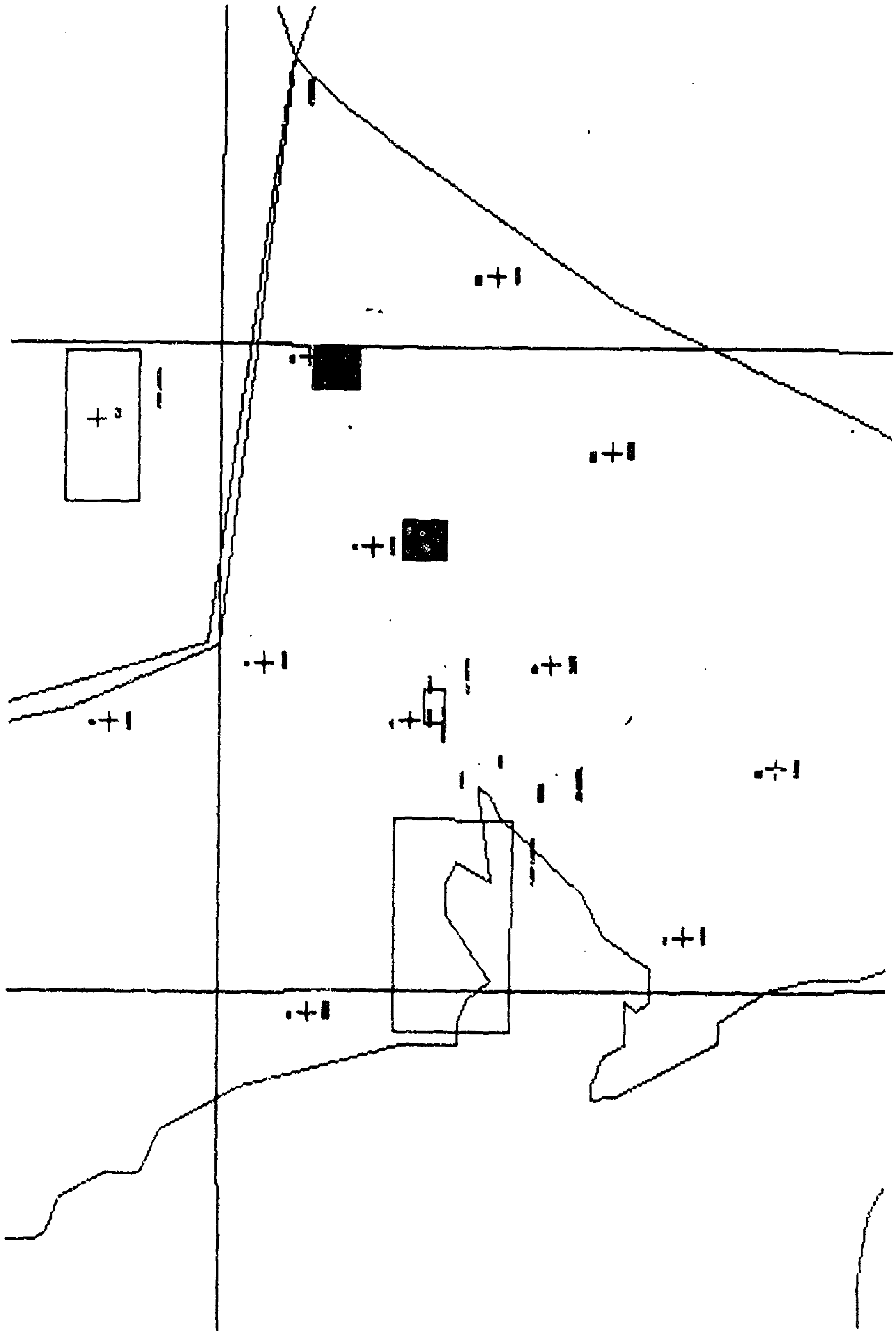

Figure 4-4 Lower Level Active Radar Coverage of

the IMOM State Space for SCENARIO 1

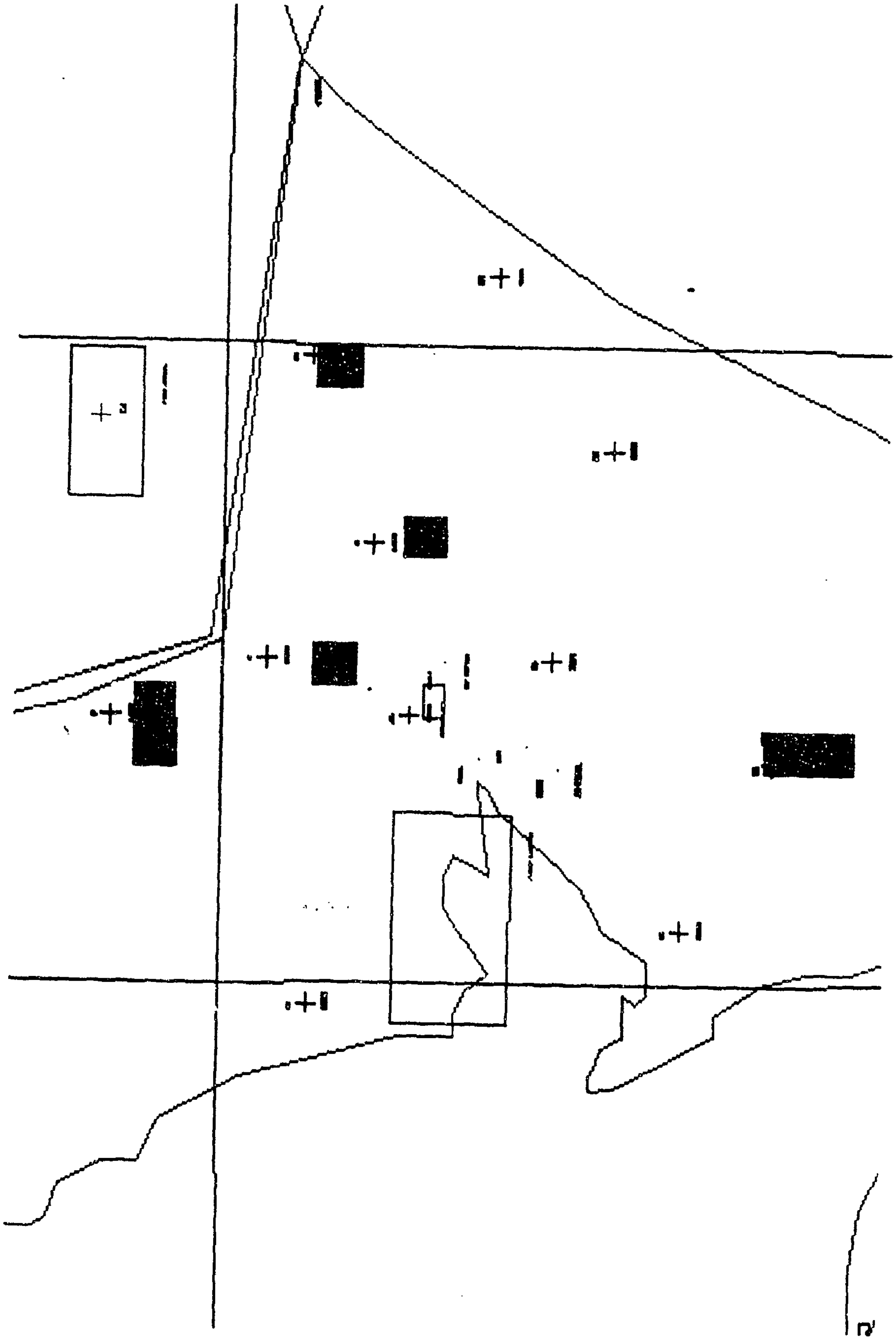

Figure 4-5 Upper Level Active Radar Coverage of

the IMOM State Space for SCENARIO 1

problems using ADBASE are found in appendix 4. The filter subprogram was used to eliminate the dominated routes from the aggregated results of all nine ADBASE runs. The aggregated results of the nondominated efficient alternatives using all three criteria and the IMOM generated route are given in table 4-4.

TABLE 4-4
NONDOMINATED ROUTES FOR SCENARIO 1

ROUTE NUMBER	DISTANCE	ACTIVE EXPECTED VALUE	PASSIVE EXPECTED VALUE
1	95.7	.650	33.77
2	106.7	.412	50.60
3	97.7	.590	40.99
4	102.4	.778	19.29
5	98.1	.416	21.97
6	96.2	1.126	21.97
7	96.2	1.075	28.21
8	107.0	1.354	15.65
IMOM(9)	96.9	0.000	44.92

The process of filtering continued in both the reverse and forward modes to illustrate the FILTER subprogram as an aid to human decision making. The forward and reverse filtering options were subjectively chosen to determine only three routes. The route chosen to seed (Route Number 1) the reverse filter was arbitrarily chosen to demonstrate the interactive decision making process of the FILTER subprogram. Route number 5 was arbitrarily chosen as the preferred alternative from the reverse filtering results. A

three dimensional representation of the filtering processes is given figure 4-6. The Tektronix representation of the route chosen from the research methodology is given in figure 4-7.

As a decision aid, the three dimensional representation of the nondominated routes presents a confusing comparison of alternatives. In order to arrive at an informed decision a simpler and more understandable representation of the alternatives is needed. A second method to illustrate the alternative merits is presented in a more comprehendible format of two dimensions. The second method is to plot the routes as a function of two criteria. These representations are given in figures 4-8 thru 4-10. The decision maker can then choose the alternative based on the plotted criteria he feels are the most important to mission success. The plots reveal the efficient frontiers or nondominated routes when evaluated with only two-criteria. The efficient frontiers were determined by measuring a two-criteria, Pareto-optimality for all the nondominated alternative routes. The numbered routes situated along the efficient frontier present the relative criterion values for each alternative. The remaining criteria vectors (dominated routing alternatives) are plotted as points (dominated criterion vectors) in the dominated region of the graph.

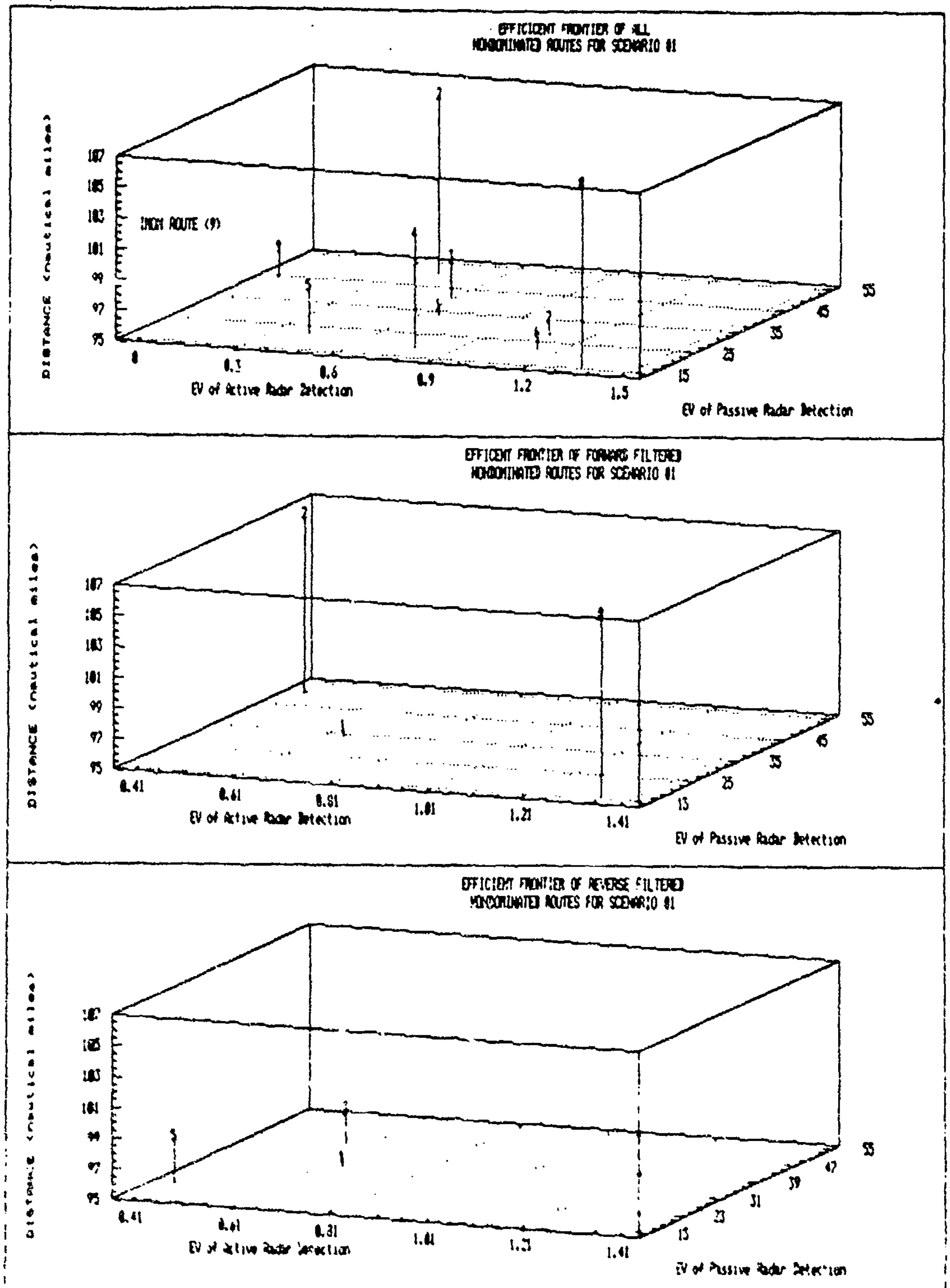

Figure 4-6 Forward and Reverse Filtering of Nondominated Routes in SCENARIO 1

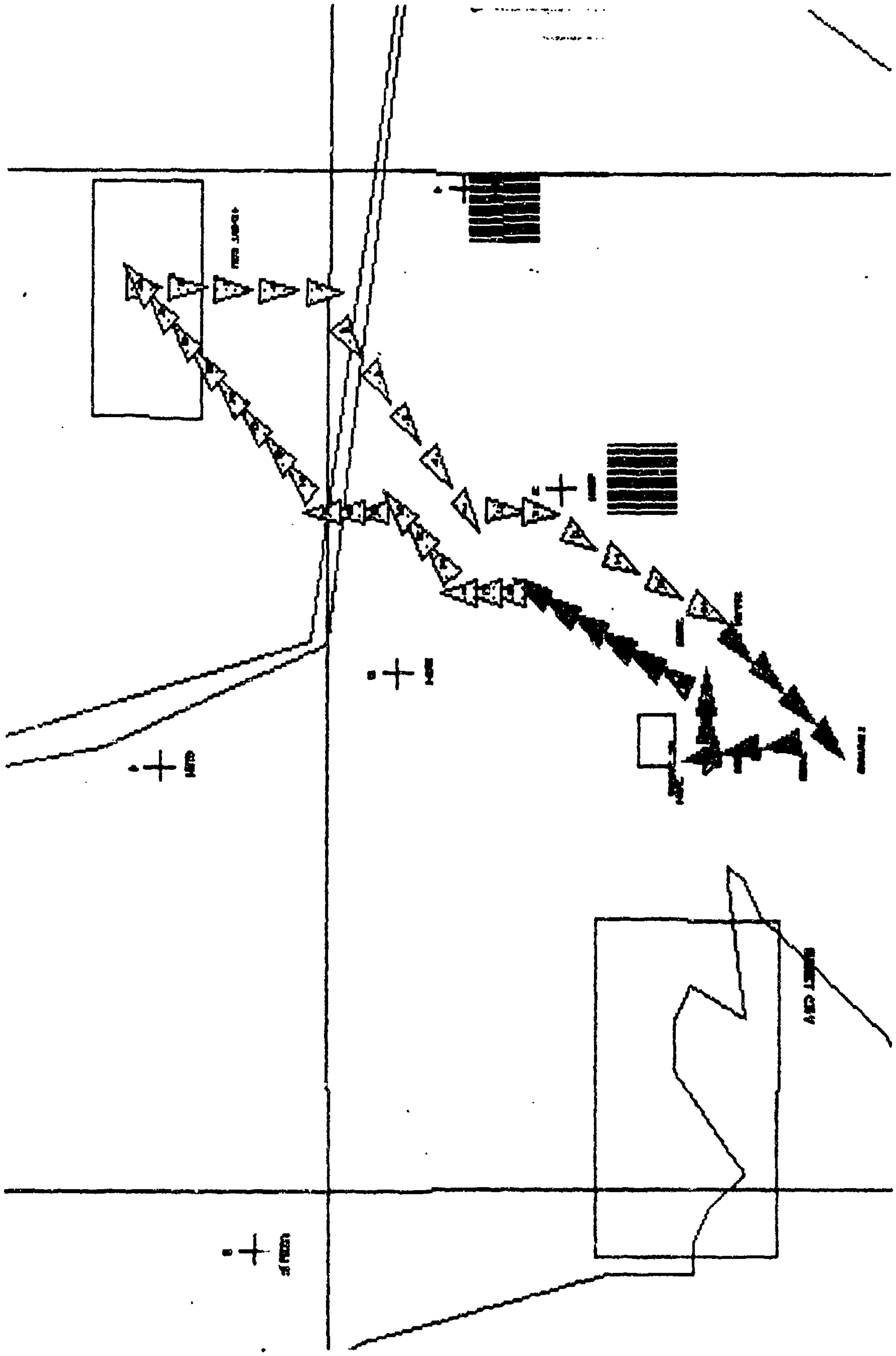

Figure 4-7 Route Number 5 in the IMOM

State Space for SCENARIO 1

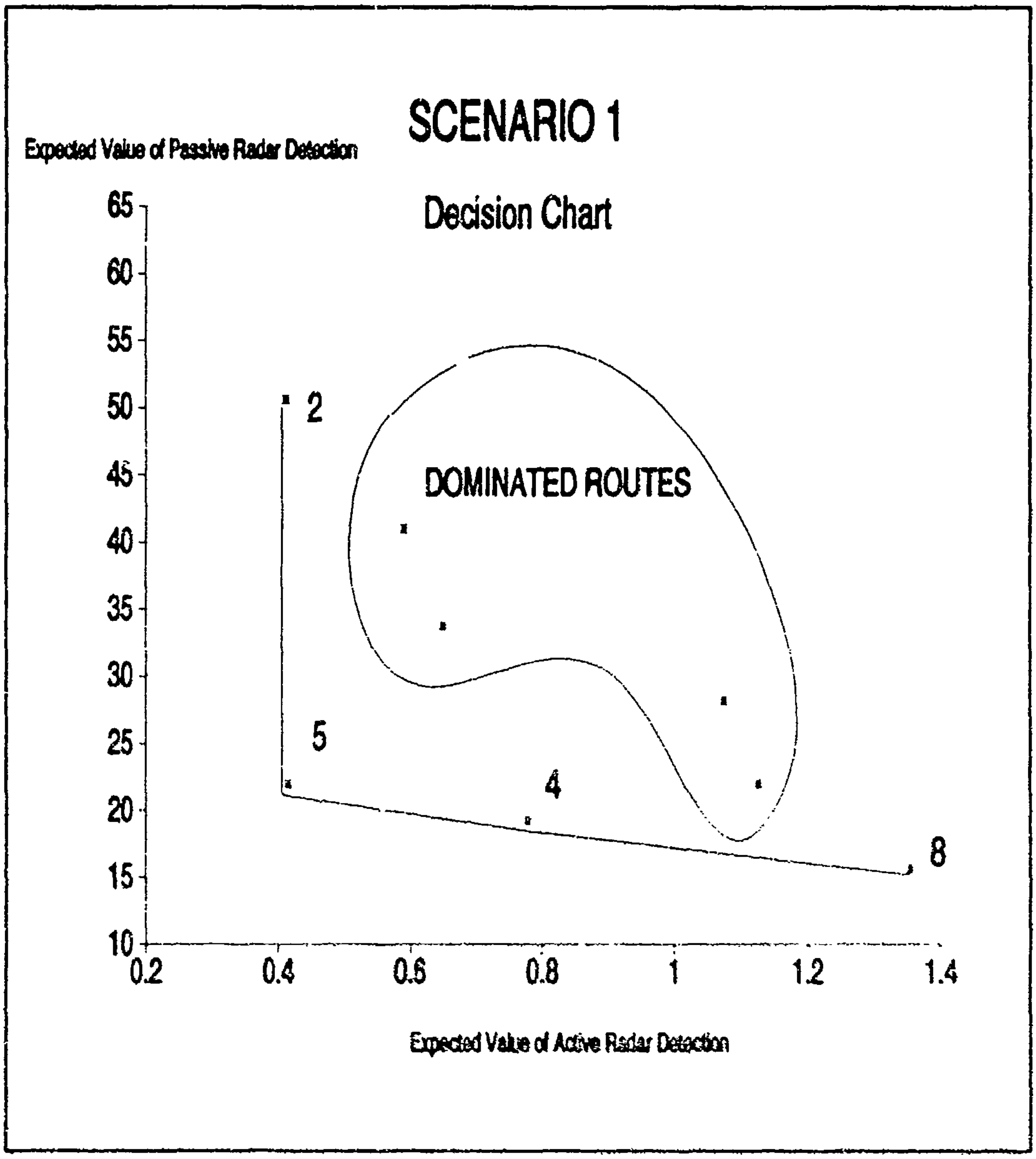

Figure 4-8 Numbered Nondominated Routes
Active versus Passive Detection Expected Value

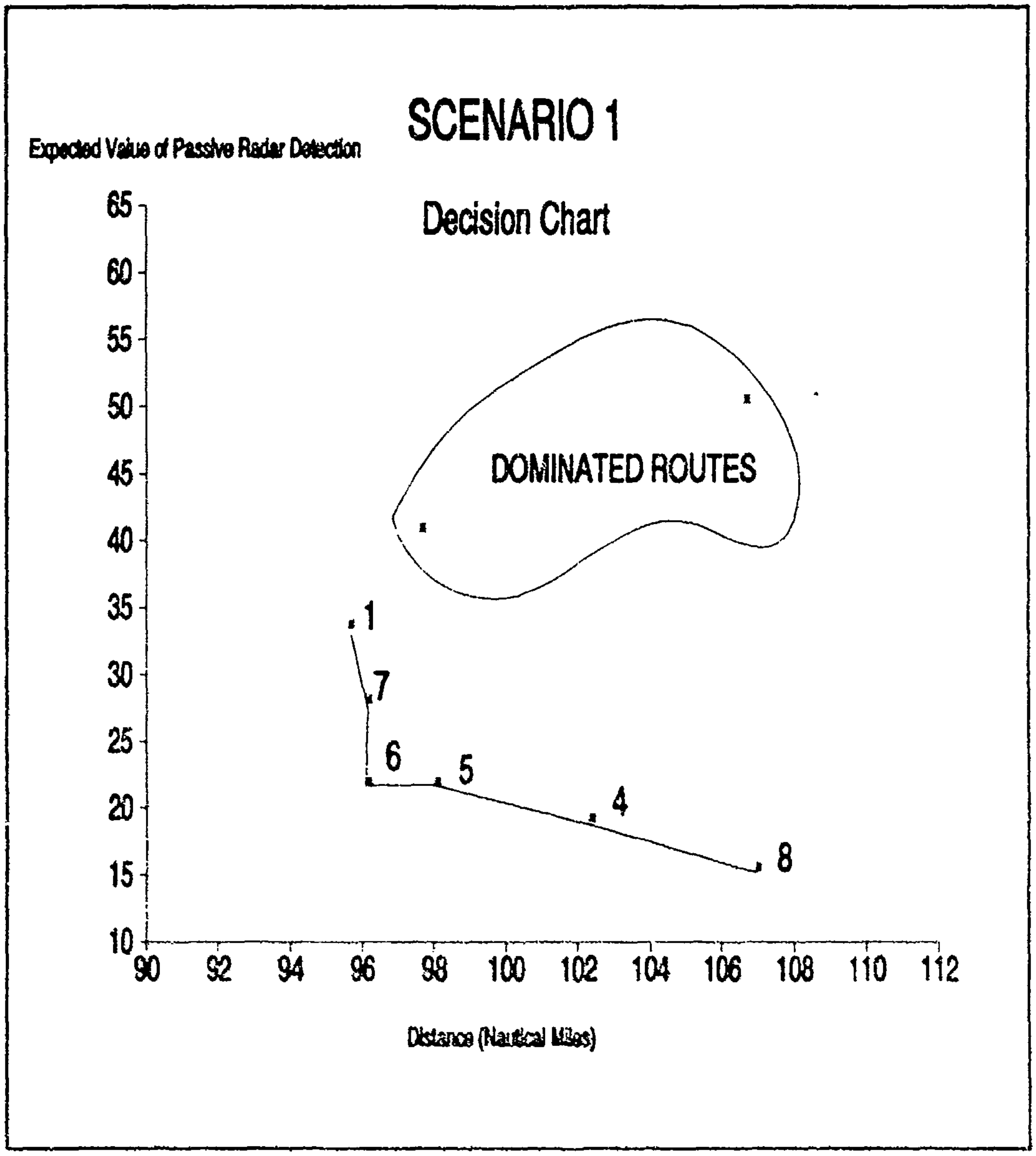

Figure 4-9 Numbered Nondominated Routes
Passive Detection Expected Value versus Distance

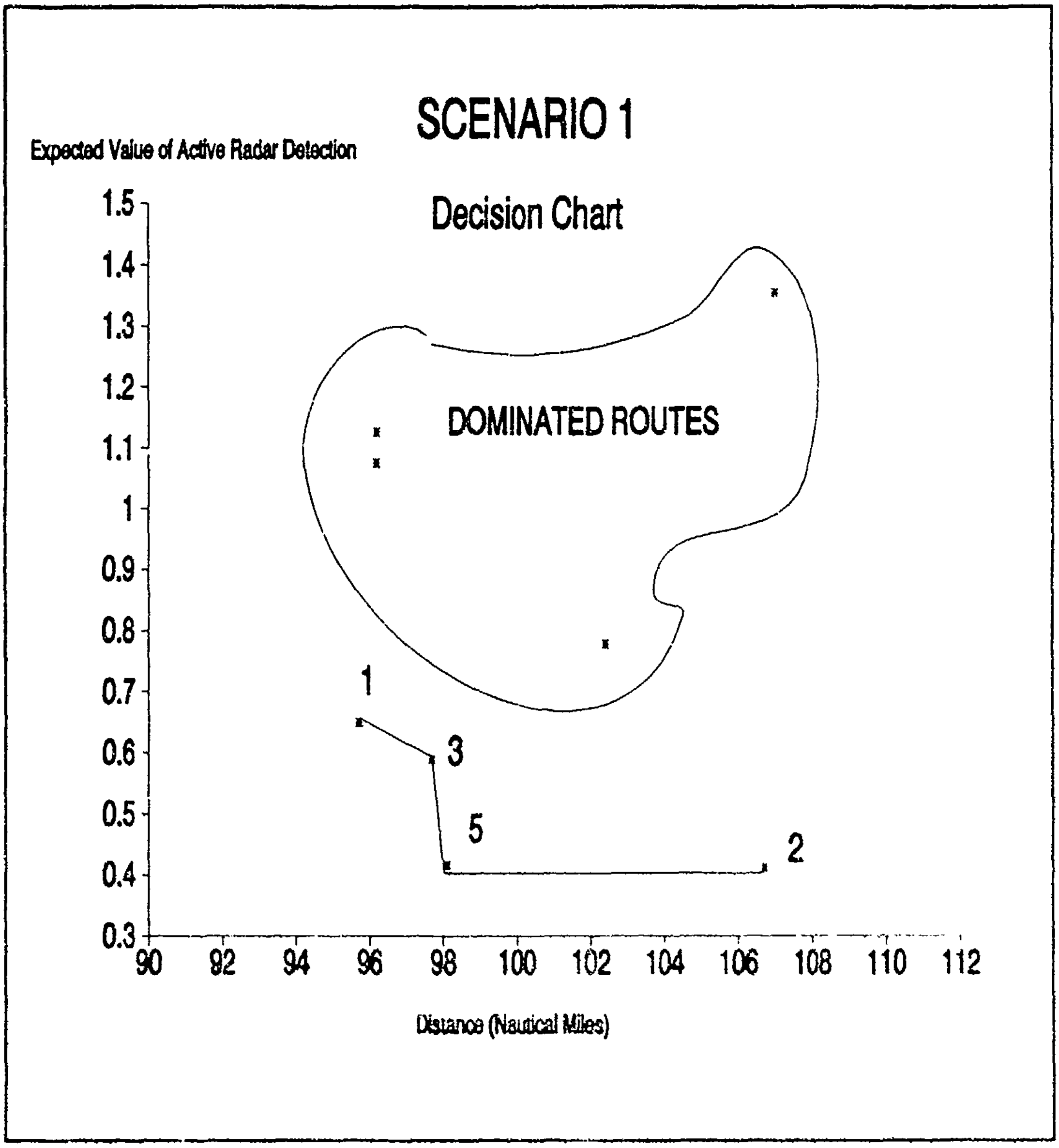

Figure 4-10 Numbered Nondominated Routes
Active Detection Expected Value versus Distance

The methodology for determining the distance and risk expected values is identical in all three scenarios. Additionally, the filtering of the criterion vectors which represent specific routes is replicated in the same manner.

Scenario Two. The second scenario is given in figures 4-11 and 4-12. The state spaces in both figures represent the lower and upper level radar coverages respectively. The types and locations of the electronic order of battle for the second scenario are given as follows:

TABLE 4-5
SCENARIO 2 ELECTRONIC ORDER OF BATTLE

WEAPON SYSTEM	NUMBER OF SYSTEMS	LOCATION LATITUDE	LONGITUDE
FAR VIEW	3	291556N	461634E
		300537N	465614E
		285542N	480327E
GUN 1	5	285013N	473512E
		290401N	472940E
		290740N	472940E
		291321N	471846E
		294856N	473921E
SAM	1	294057N	475457E
SAM	2	290751N	480159E
		292407N	465321E

The results of the generalized dynamic program for the nine sets of λ_i values are given in appendix 3. The ADBASE results from scenario two are in appendix 4.

The aggregated results of the nondominated efficient routes are given in table 4-6. The graphical results of the filtering process is given in figure 4-13. Route Number 1

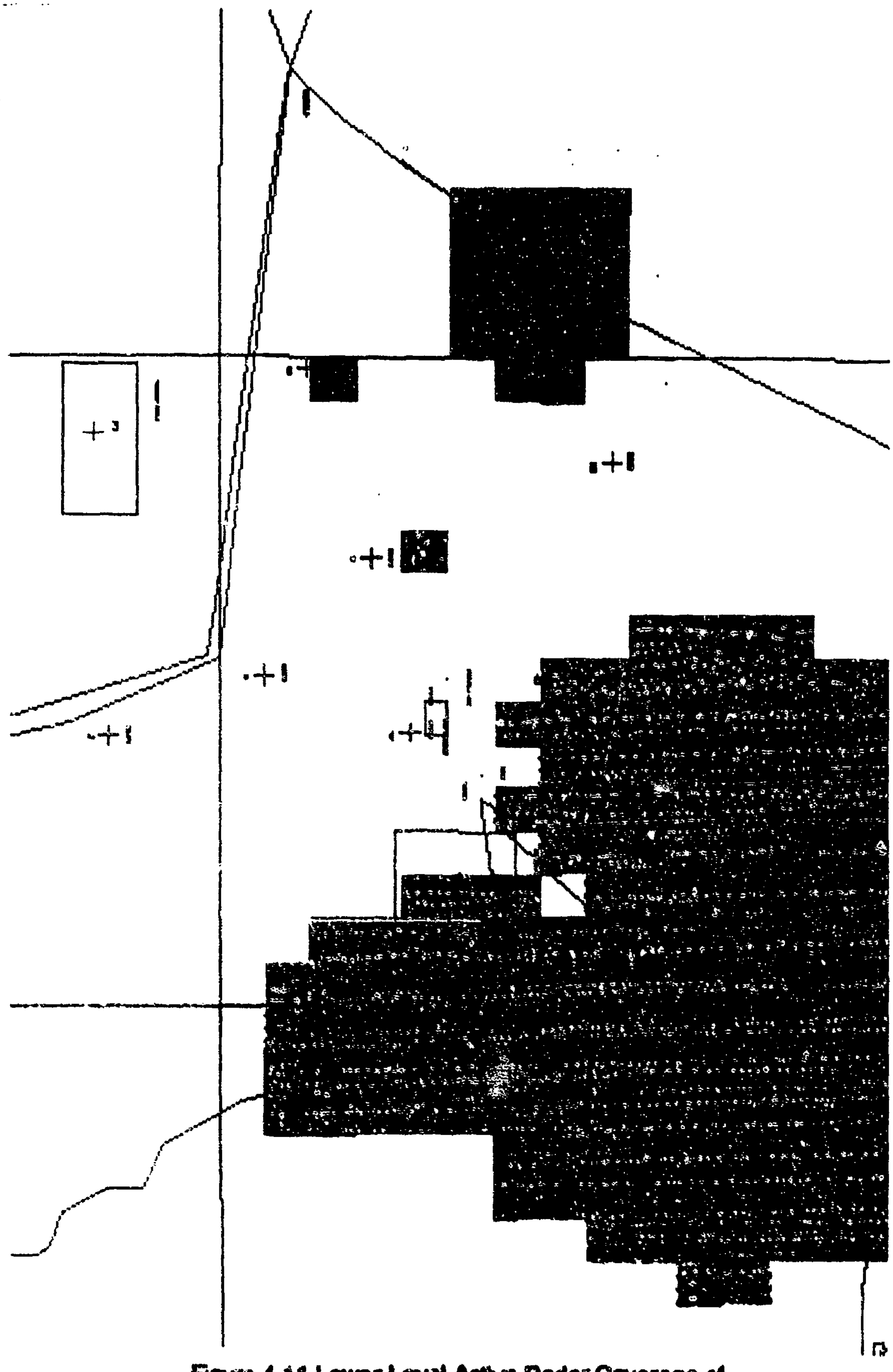

Figure 4-11 Lower Level Active Radar Coverage of

the IMOM State Space for SCENARIO 2

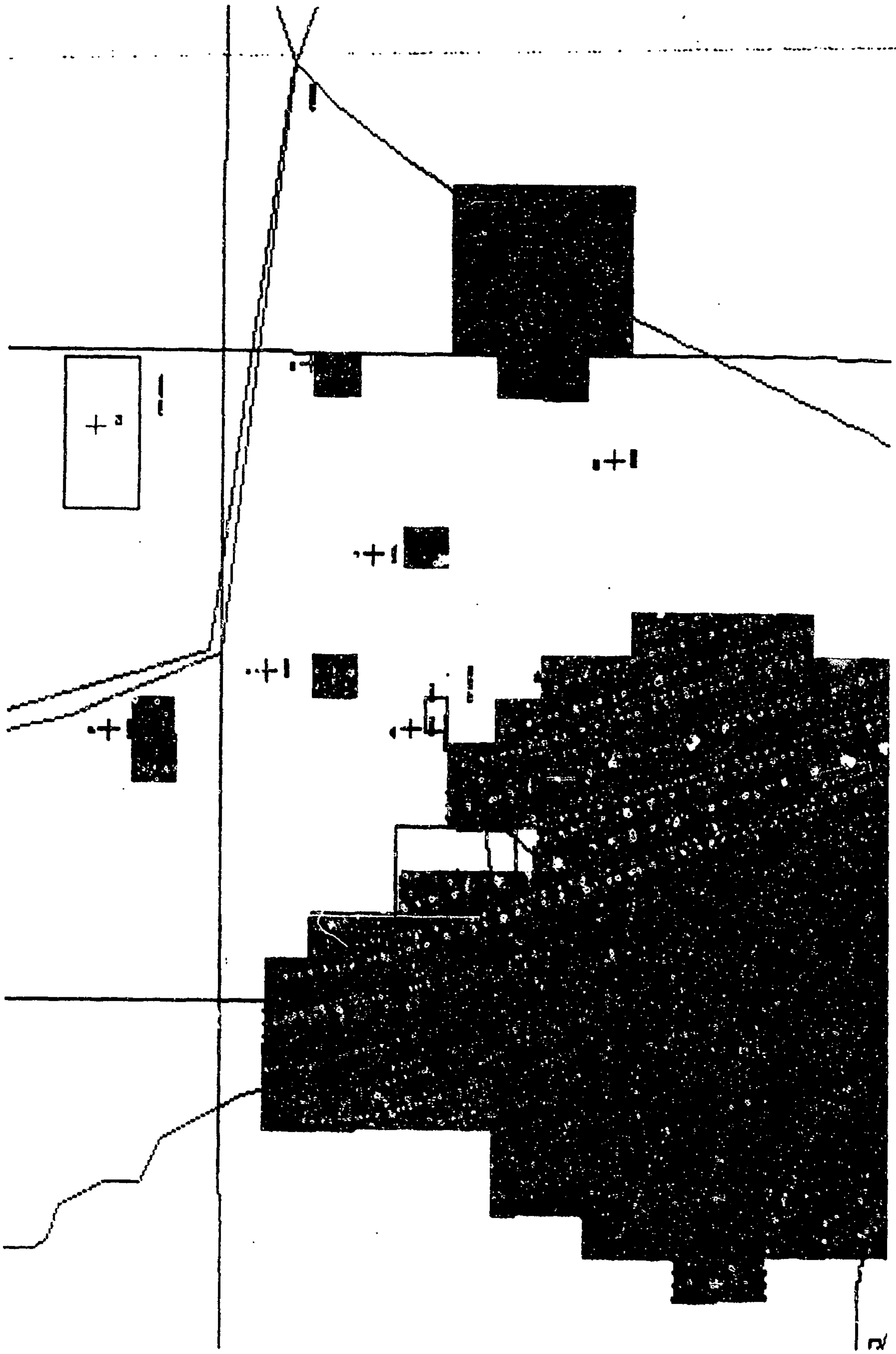

Figure 4-12 Upper Level Active Radar Coverage of the IMOM State Space for SCENARIO 2

was chosen as the seed value in the reverse filtering process. Route Number 5 was arbitrarily chosen as the preferred route from the reverse filtering results. The Tektronix representation of the route chosen from the research methodology is given in figures 4-14.

TABLE 4-6
NONDOMINATED ROUTES FOR SCENARIO 2

ROUTE NUMBER	DISTANCE	ACTIVE EXPECTED VALUE	PASSIVE EXPECTED VALUE
1	98.2000	4.3560	22.0400
2	109.7000	3.5880	29.5700
3	81.9000	5.5720	44.1200
4	86.7000	4.7250	50.6000
5	95.7000	4.5730	33.7700
6	102.5000	4.8110	17.0600
7	96.3000	4.4200	24.2700
8	96.3000	4.4830	24.2000
9	107.5000	3.7010	29.7100
10	105.4000	3.5470	35.0600
IMOM(11)	96.9000	2.8300	44.9200

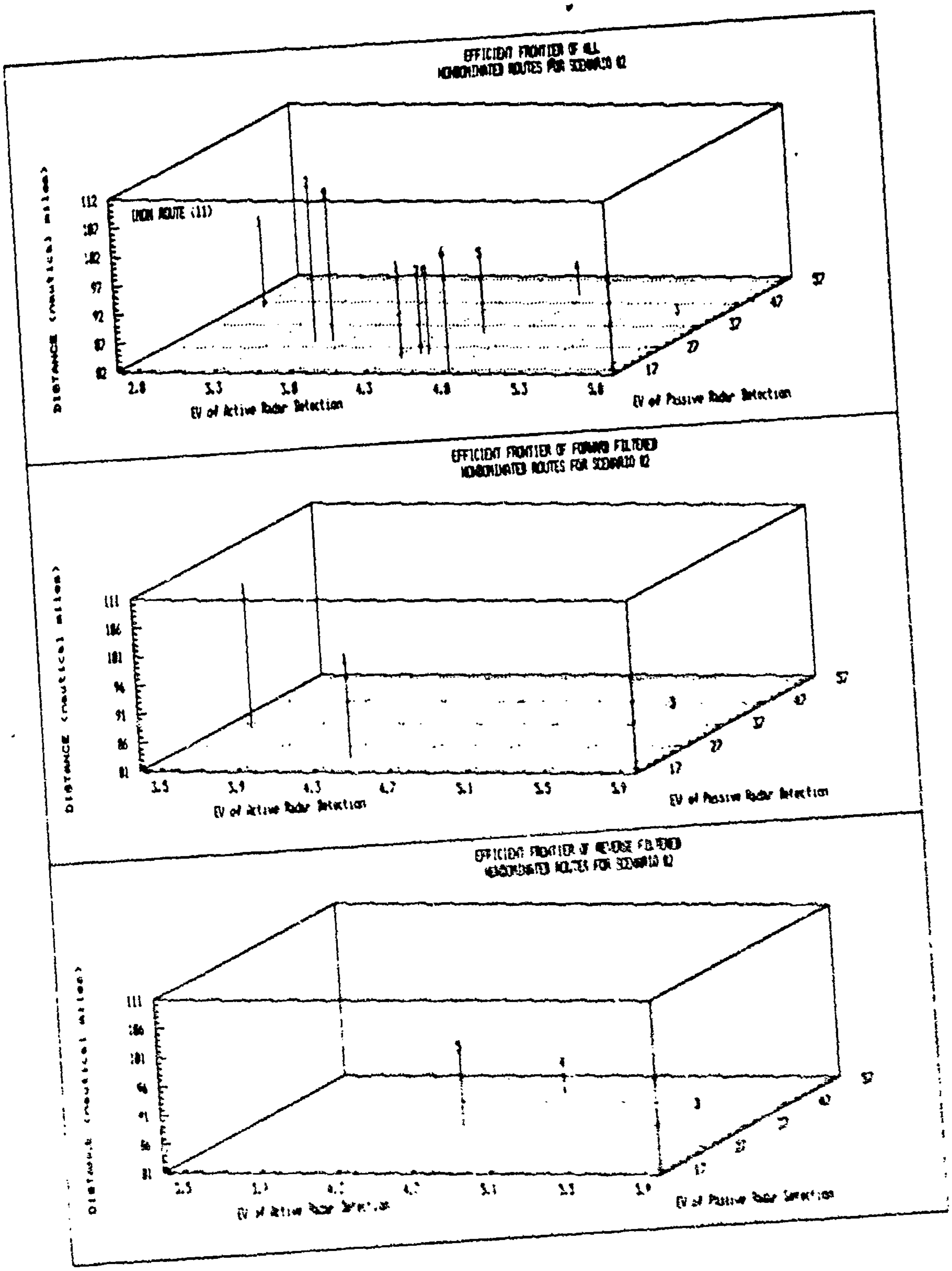

Figure 4-13 Forward and Reverse Filtering of Nondominated Routes in SCENARIO 2

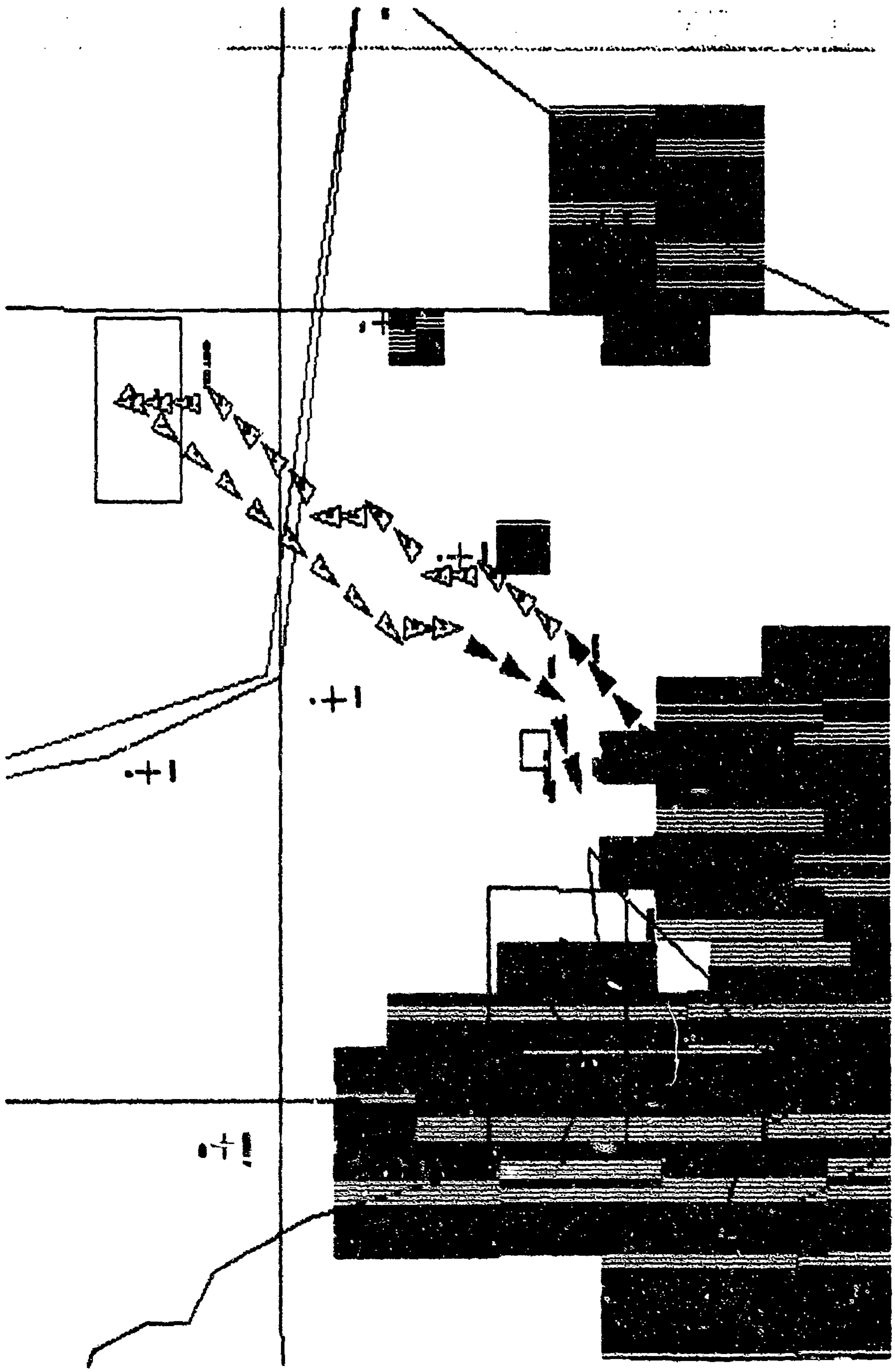

Figure 4-14 Route Number 5 in the MOM

State Space for SCENARIO 2

The second method of presenting the decision maker with the alternative routes is shown in figures 4-15 thru 4-17.

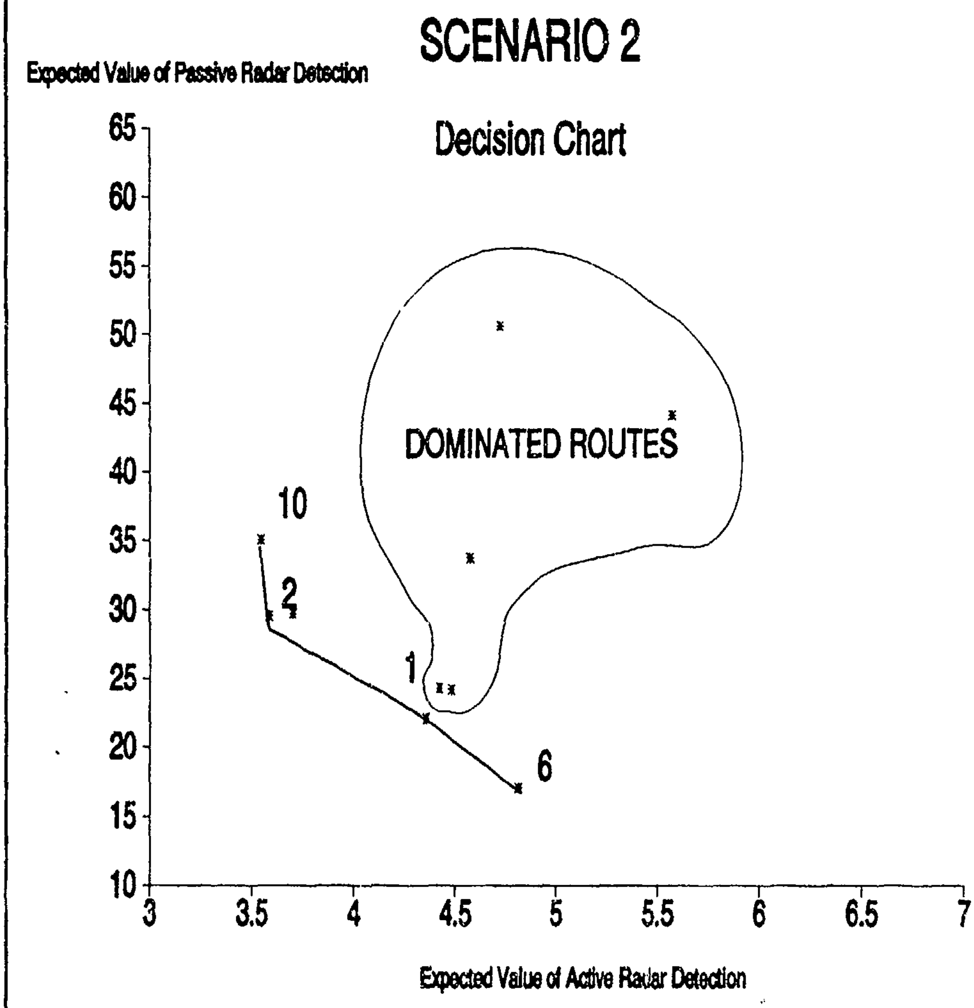

Figure 4-15 Numbered Nondominated Routes
Active versus Passive Detection Expected Value

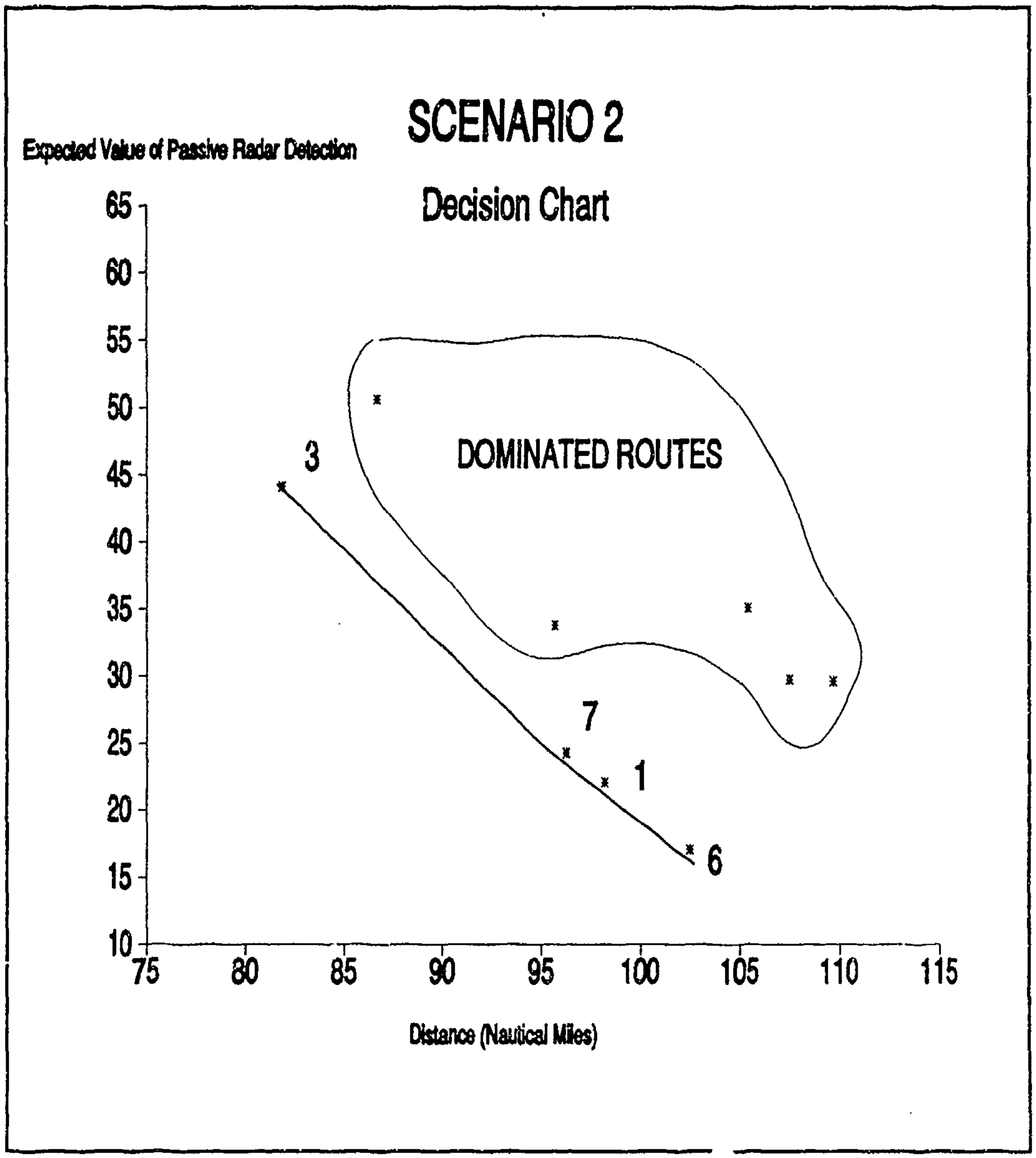

Figure 4-16 Numbered Nondominated Routes
Passive Detection Expected Value versus Distance

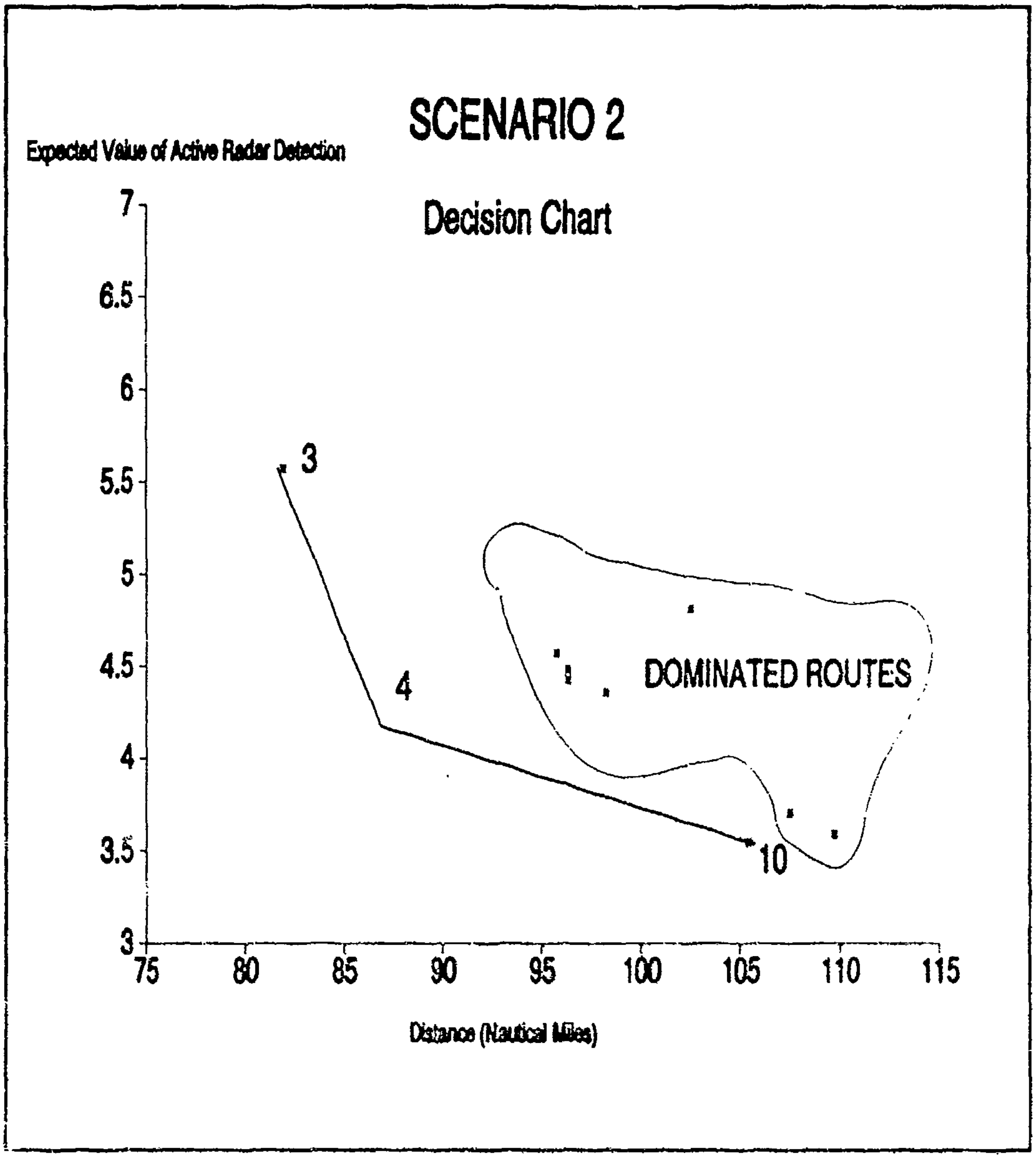

Figure 4-17 Numbered Nondominated Routes
Active Detection Expected Value versus Distance

Scenario Three The third scenario is given in figures 4-18 and 4-19. The state spaces in both figures represent the lower and upper level radar coverages respectively. The weapon systems and locations of the electronic order of battle for the second scenario are given in table 4-7.

TABLE 4-7
SCENARIO 3 ELECTRONIC ORDER OF BATTLE

WEAPON SYSTEM	NUMBER OF SYSTEMS	LOCATION LATITUDE	LONGITUDE
FAR VIEW	3	291556N	461634E
		300537N	465614E
		285542N	480327E
GUN 1	5	285013N	473512E
		290401N	472940E
		290740N	472940E
		291321N	471846E
		294856N	473921E
SAM 3	1	294057N	475457E
SAM 4	3	290751N	480159E
		292407N	465321E
		293425N	470943E
SAM 5	2	291646N	473452E
		292921N	472945E

The results of the generalized dynamic program for the nine sets of λ_i values are given in appendix 3. The ADBASE results for scenario three are in appendix 4. The aggregated results of the nondominated efficient routes are given in table 4-8. The graphical results of the

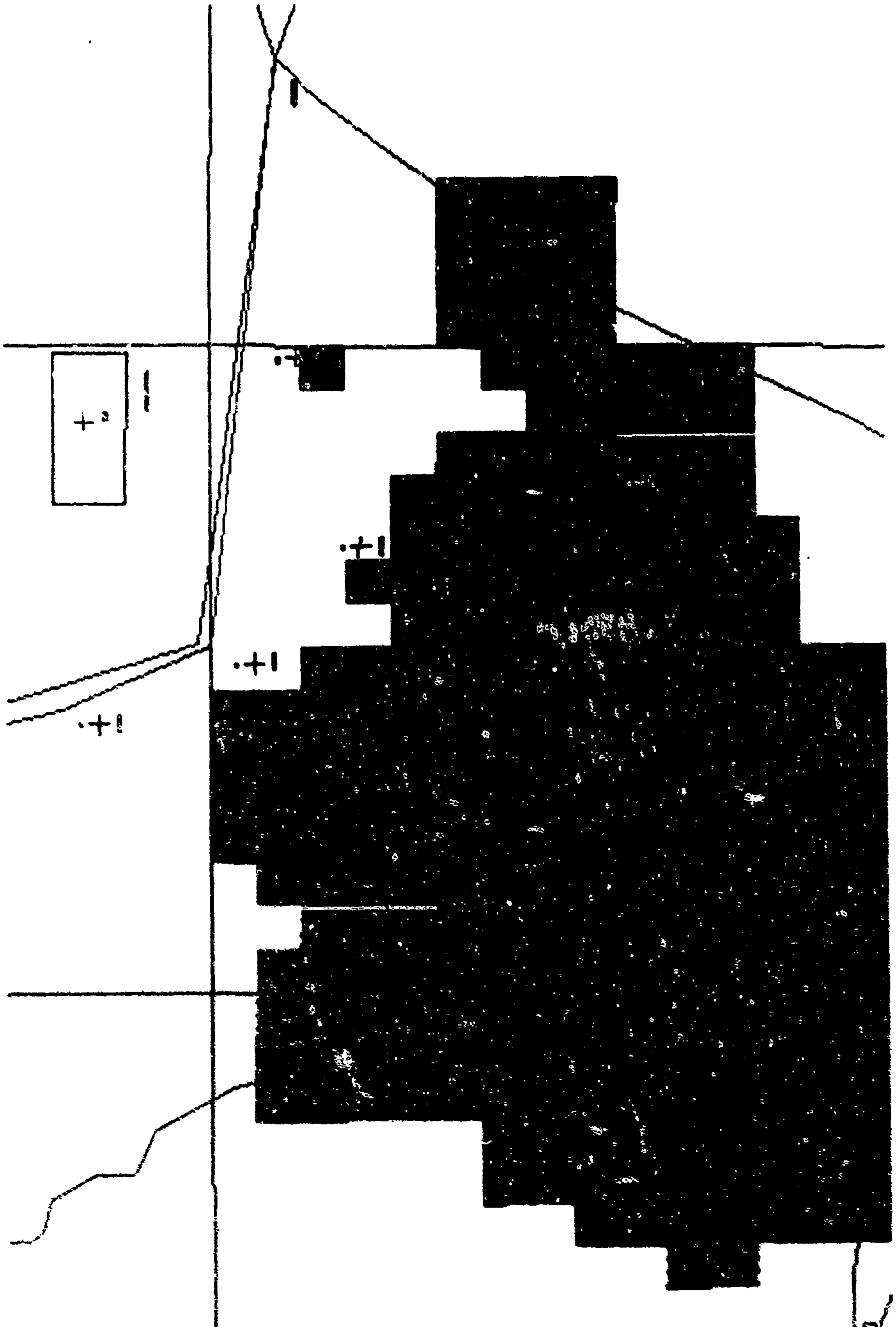

Figure 4-18 Lower Level Active Radar Coverage of

the IMOM State Space for SCENARIO 3

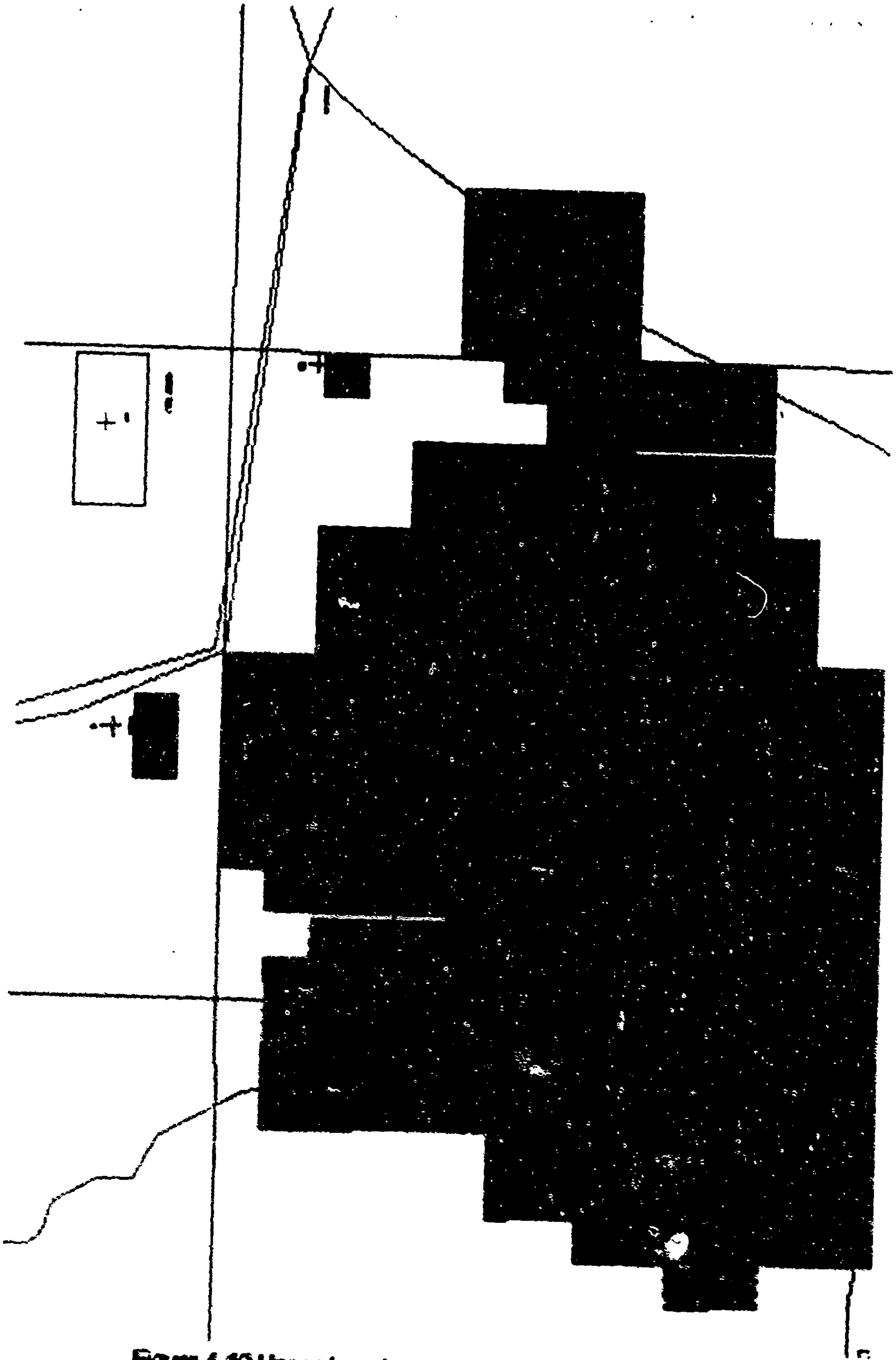

Figure 4-19 Upper Level Active Radar Coverage of

the IMOM State Space for SCENARIO 3

filtering process is given in figure 4-20. Route Number 2 was chosen as the seed value. From the reverse filtering alternative set Route Number 4 was chosen as the preferred option. The Tektronix representation of the route chosen from the research methodology route is given in figure 4-21.

TABLE 4-8
NONDOMINATED ROUTES FOR SCENARIO 3

ROUTE NUMBER	DISTANCE	ACTIVE EXPECTED VALUE	PASSIVE EXPECTED VALUE
1	95.7	15.33	35.18
2	98.4	15.82	22.19
3	102.7	17.34	20.25
4	92.7	16.92	22.55
5	96.4	16.09	24.35
6	96.3	14.89	25.84
7	96.2	14.74	30.97
8	112.9	19.80	13.26
IMOM(9)	96.9	16.97	44.92

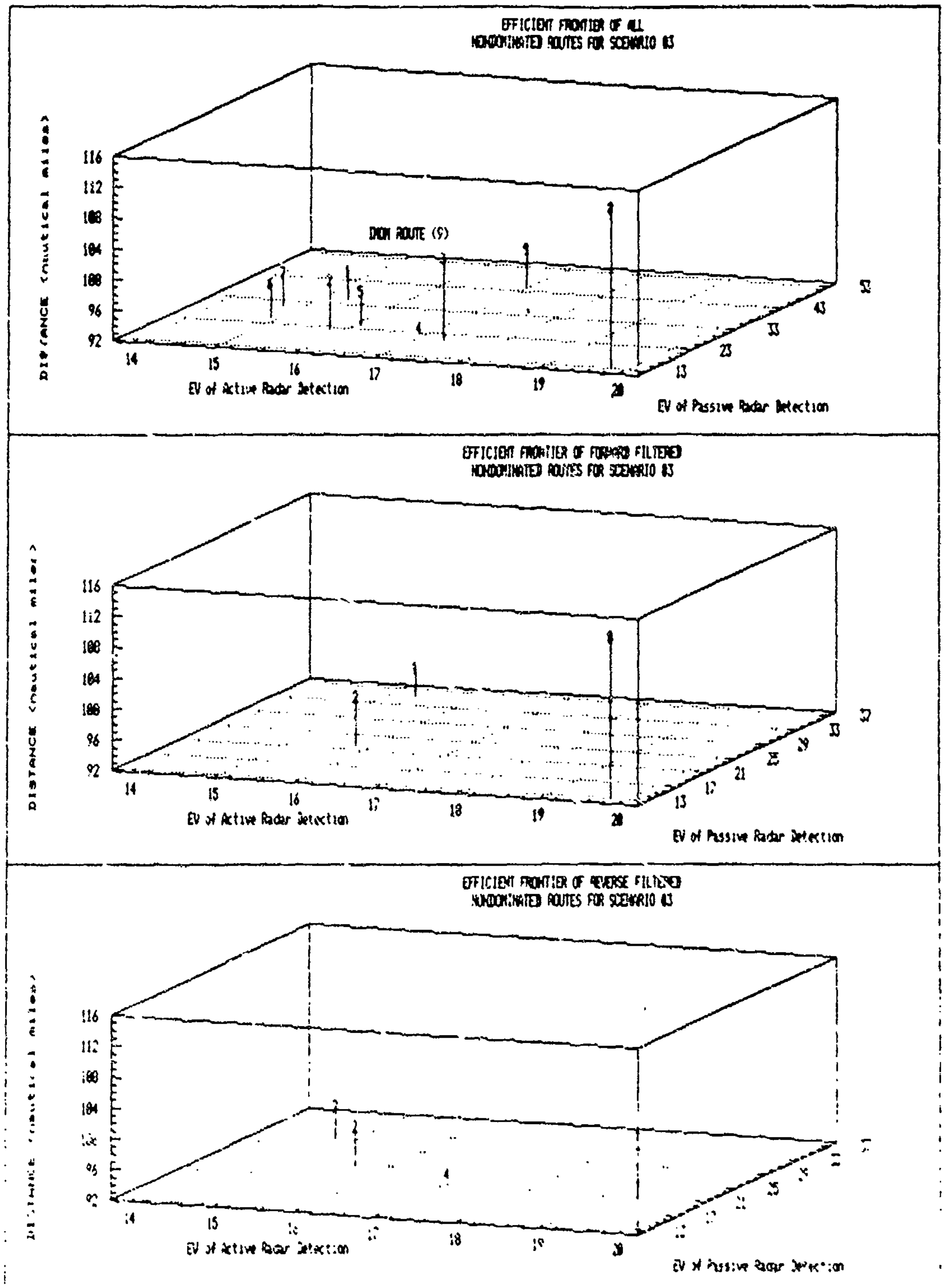

Figure 4-20 Forward and Reverse Filtering of Nondominated Routes in SCENARIO 3

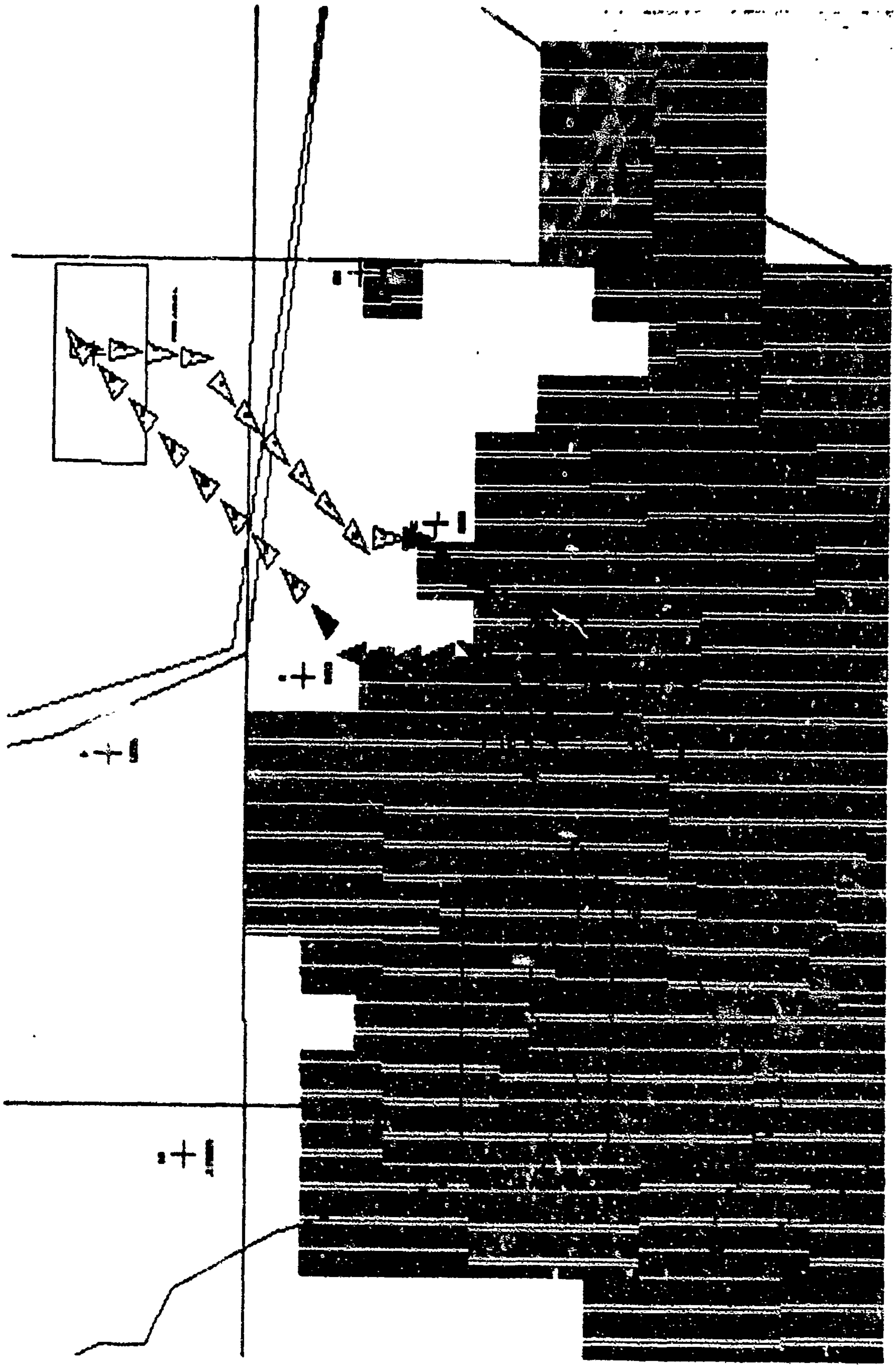

Figure 4-21 Route Number 4 in the IMOM

State Space for SCENARIO 3

The second method of presenting the decision maker with the choice of alternative routes is shown in figures 4-22 thru 4-24.

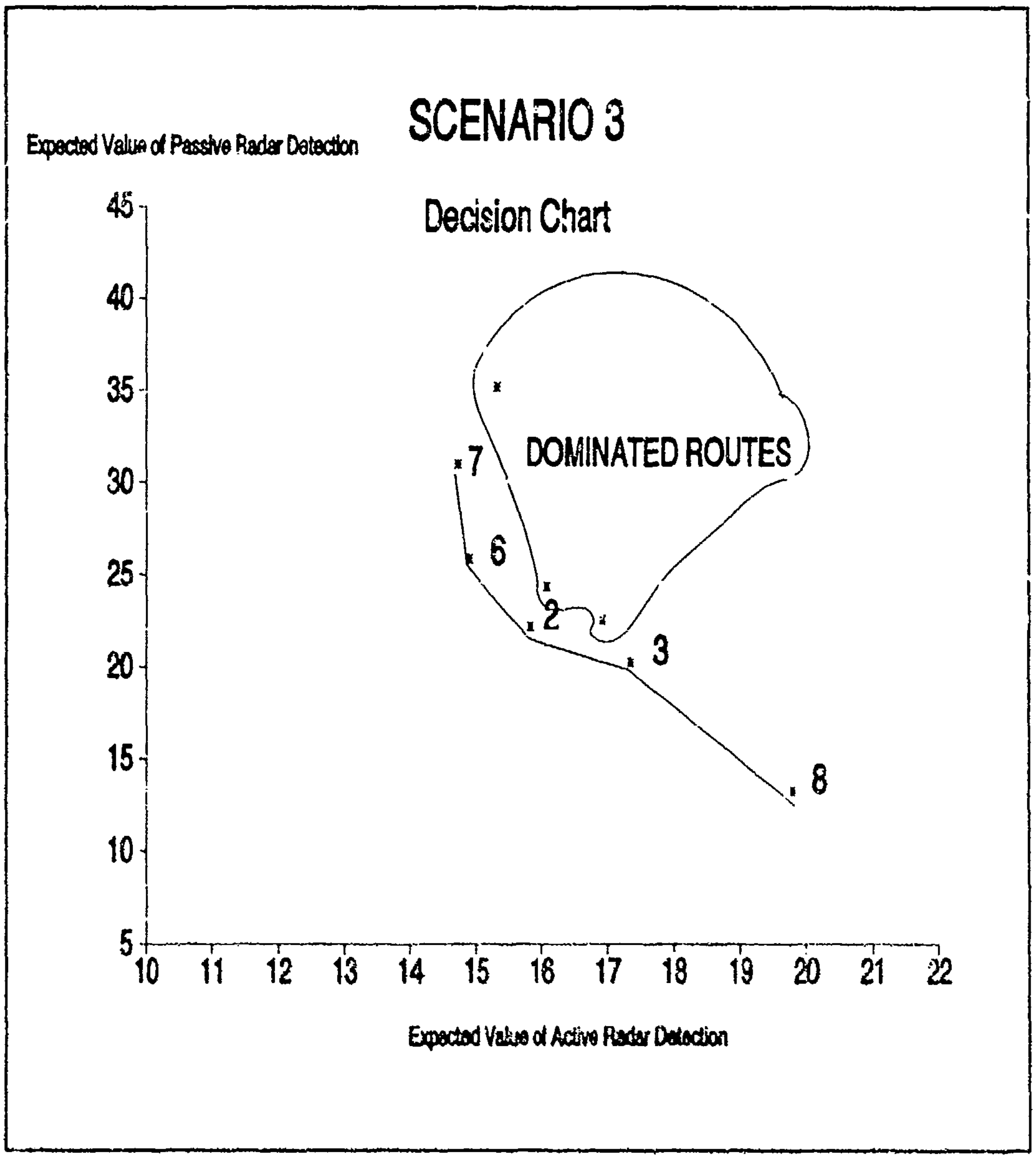

Figure 4-22 Numbered Nondominated Routes
Active versus Passive Detection Expected Value

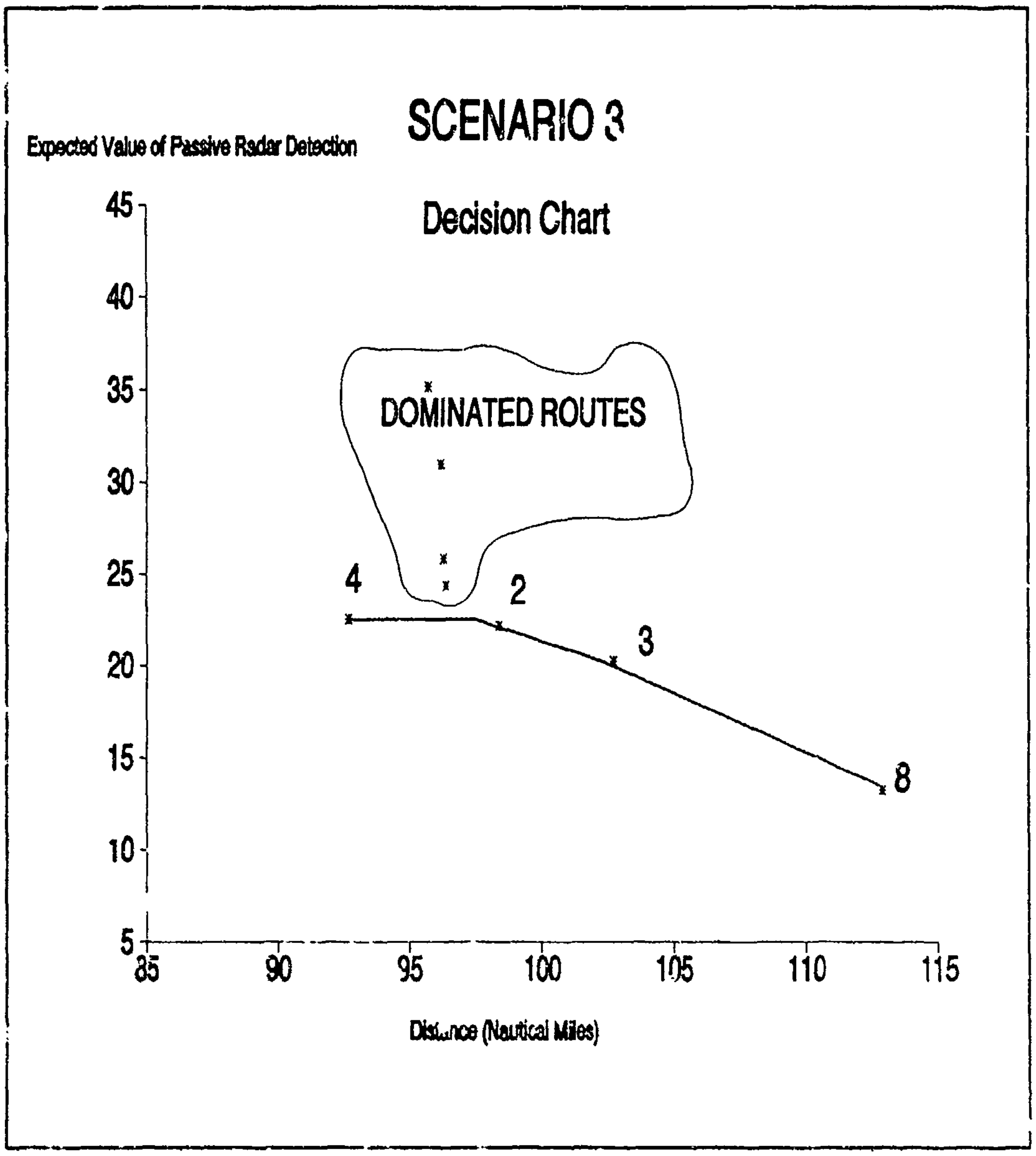

Figure 4-23 Numbered Nondominated Routes
Passive Detection Expected Value versus Distance

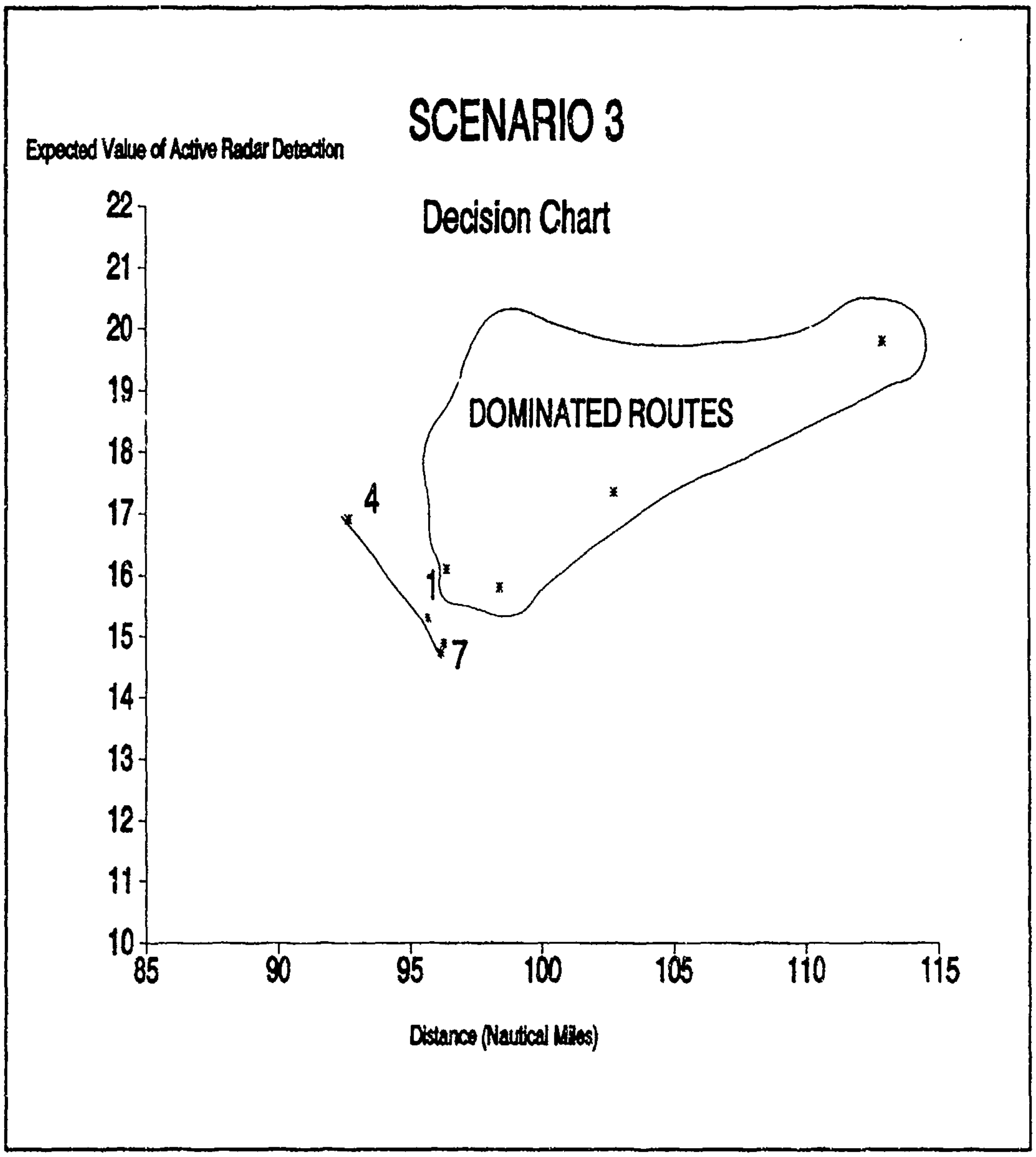

Figure 4-24 Numbered Nondominated Routes
Active Detection Expected Value versus Distance

<u>**IMOM Generated Routes**</u>. In accordance with current doctrine, the IMOM route optimizer was used to generate ingress and egress paths at the lowest altitude level of the example network. IMOM was used to determine routes for all three scenarios. The distance and passive and active

expected values of radar detection were measured from the Tektronix prints for the IMOM generated routes. An evaluation of these paths based on all three criteria concluded that the IMOM routes were nondominated in comparison to the routes constructed from the generalized dynamic programming and ADBASE methodology. However, the IMOM routes were unable to avoid the restricted area over Al Jahra. Furthermore, the IMOM routes also duplicated ingress and egress subpaths. These shortcomings were unavoidable due to the modeling structure of the state space. Additionally, the IMOM route optimizer only produces one route. Finally, the IMOM routes were not always established along the efficient frontier of the two criteria plots. A summary of the dual criteria route plots are given in table 4-9 thru 4-11.

TABLE 4-9
NONDOMINATED ROUTE SUMMARY

SCENARIO 1

ROUTE NUMBER	ACTIVE vs PASSIVE	PASSIVE vs DISTANCE	ACTIVE vs DISTANCE	TOTAL
1		X	X	2
2	X		X	2
3			X	1
4	X	X		2
5	X	X	X	3
6		X		1
7		X		1
8	X	X		2
IMOM	X		X	2

TABLE 4-10
NONDOMINATED ROUTE SUMMARY

SCENARIO 2

ROUTE NUMBER	ACTIVE vs PASSIVE	PASSIVE vs DISTANCE	ACTIVE vs DISTANCE	TOTAL
1	X	X		2
2	X			1
3		X	X	2
4				0
5				0
6	X	X		2
7		X		1
8		X		1
9				0
10	X		X	2
IMOM	X		X	2

TABLE 4-11
NONDOMINATED ROUTE SUMMARY

SCENARIO 3

ROUTE NUMBER	ACTIVE vs PASSIVE	PASSIVE vs DISTANCE	ACTIVE vs DISTANCE	TOTAL
1			X	1
2	X			1
3		X		1
4		X	X	2
5				0
6	X			1
7	X			1
8	X	X		2
IMOM				0

As the complexity of the scenarios increase the IMOM route optimizer fails to produce an efficient route when plotted with two criteria. Even with the ability to overfly restricted areas and replicate subpaths along the ingress and egress routes, the IMOM route optimizer only appears effective in scenarios with lower-density threat coverage. IMOM's inability to determine efficient routes is partly a function of the cell-to-cell movement restrictions in the state space. However, these movement restrictions in the state space also allow the IMOM generated route to overfly the restricted areas and duplicate ingress and egress subpaths. Since the network structure and resolution significantly impact routing efficiency a comparison of the research methodology and the IMOM program does not validate

the techniques of generalized DP. An examination of conventional DP and the point-to-point model is required to determine the effectiveness of the research methodology in determining nondominated routes.

Comparison with Conventional Dynamic Programming

A limited comparison of path generation was completed between the extension of Dijkstra's Algorithm for multicriteria conventional and generalized dynamic programming. Conventional dynamic programming was used to find the efficient ingress paths for all three scenarios along the point-to-point network. The limited time available restricted a complete analysis of the conventional DP routes generated by ADBASE. However, the conclusions of these limited studies strongly indicate that conventional DP would result in dominated routes when compared to routes generated by the research methodology.

In every case examined the generalized dynamic programming method resolved paths with objective function values that were as good or better than those from conventional dynamic programming, resulting in a more efficient path. In terms of Pareto-optimality the conventional-DP generated paths were dominated in comparison to generalized DP. For the ingress paths between the staging area and the targets, conventional and generalized dynamic programming objective functions were almost always

equal. The largest difference occurred between targets. The comparisons of objective function values for generalized and conventional DP is given in figure 4-25.

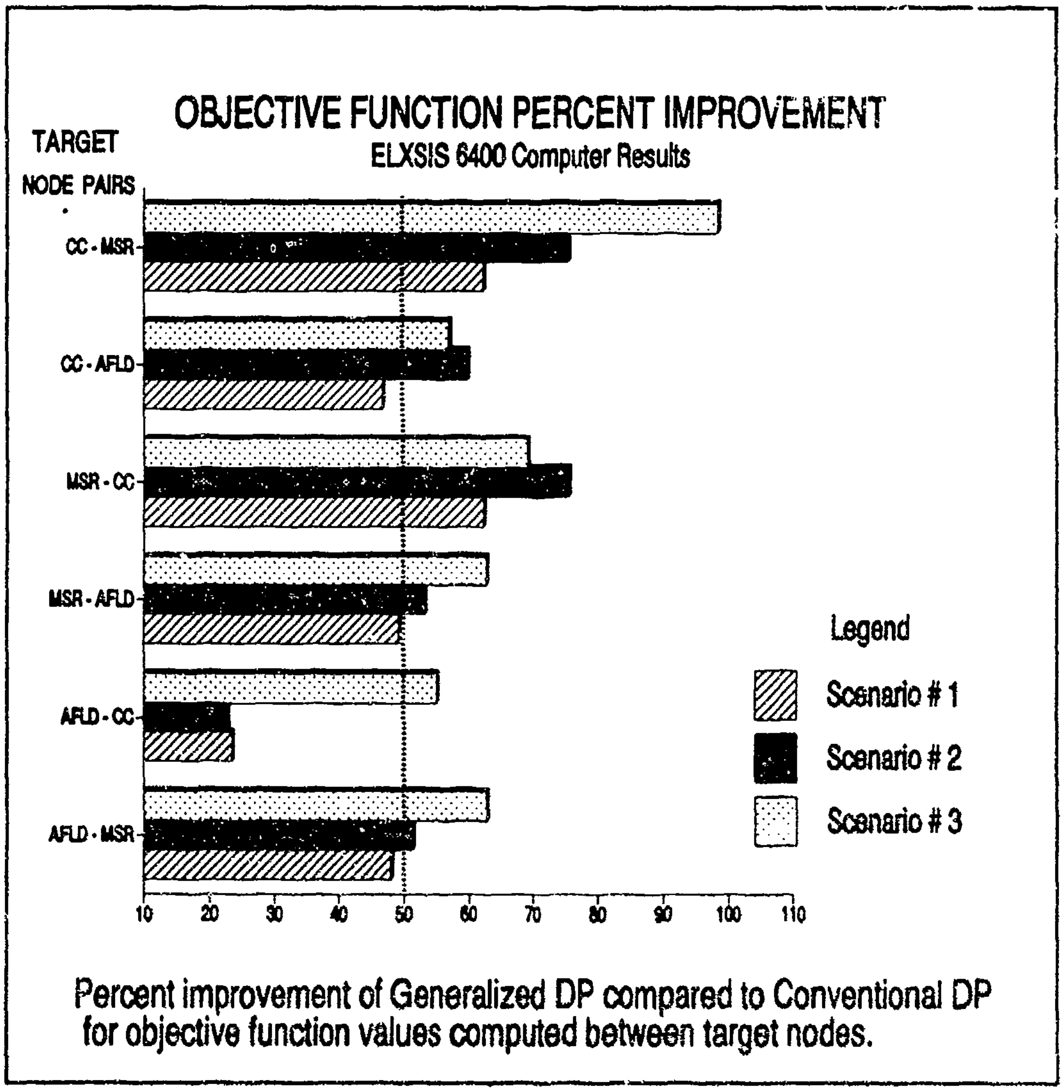

Figure 4-25 Comparison of Objective Function Values

Processing Time Comparisons With the requirement for real-time route generation the comparison of conventional and generalized dynamic programming processing duration was compiled. In every case examined generalized

DP took more CPU time to process than conventional DP. Since the removal of the ingress path was a time consuming procedure manual process the compilation of processing times for the egress paths were beyond the scope of this study. Although the generalized dynamic programming takes advantage of Dijkstra's algorithm, the subroutines which compute minima extrema resulting in additional computing time. It was observed that as the complexity of the scenario escalated, the average increase in computing time of generalized dynamic programming over the conventional form significantly lengthened. The results of the comparative processing times is given in figure 4-26. The figure delineates the increased processing requirements of generalized dynamic programming in comparison to the conventional method. It was also noted that generalized DP required approximately 15 to 45 minutes to process on a SUN 386i with math coprocessor. The SUN machines approximate the computing capability found in field units required to plan tactical aircraft routes under real-time constraints. The relatively short processing time for determining paths with the ELXSIS 6400 does not accurately reflect the capabilities that exist in a tactical unit.

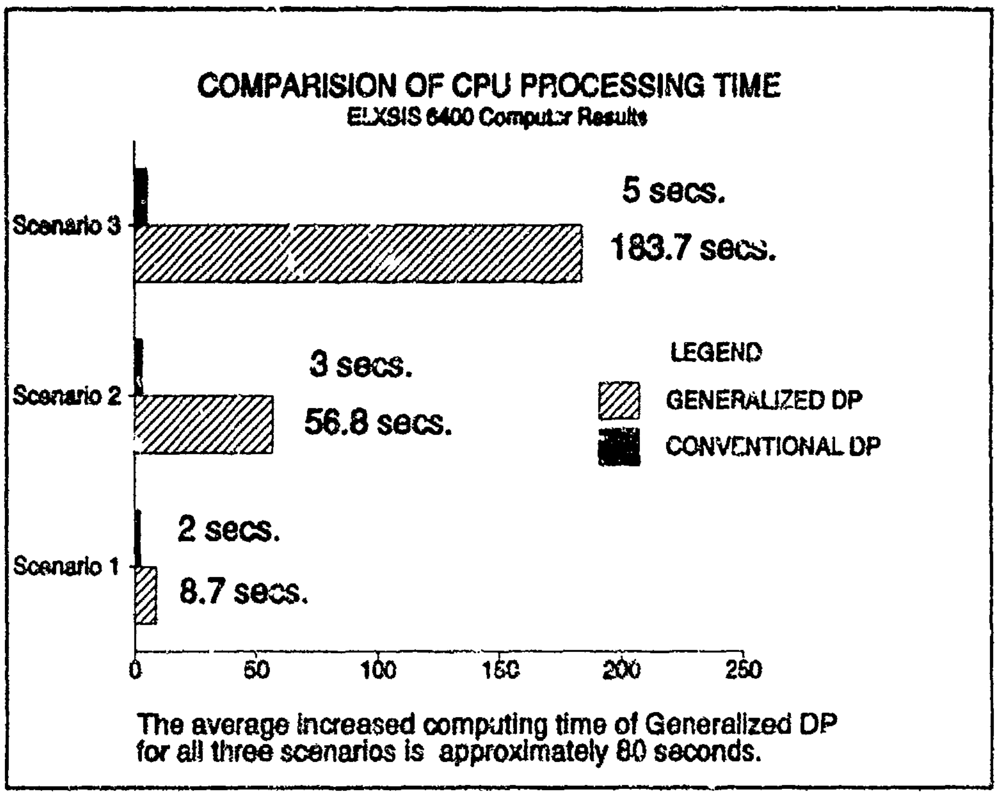

Figure 4-26 Comparison of Conventional and Generalized DP Processing Times

The subroutines used in the generalized DP extension of Dijkstra's algorithm extended processing times for path generations. Each subroutine uses Dijkstra's algorithm to determine the minima extrema. Although the number of computations of efficient subpaths required in Dijkstra's algorithm is equal to the number of network nodes, the repeated use of these subroutines increased the processing time.

Chapter - 5 Conclusions and Recommendations

Introduction

The primary research objective for this study was to determine a methodology for routing in a multicriteria graph However, a secondary objective to enhance the IMOM state space lead to the development of an extensive point-to-point network. The resulting conclusions drawn from the extensive analysis of these objectives provide several recommendations for further studies and enhancements to IMOM.

Network Modeling and Large-Scale Graphs

The advantages of a point-to-point network allows an increased dimensionality of multiple altitudes and a higher resolution of representative cost values. The point-to-point method also allows the capability to maneuver in a greater number of directions than a cell-to-cell model. Finally, man-made terrain features, restricted areas and other militarily significant battlefield obstacles can be modeled into the routing network.

Several disadvantages are also noted with the point-to-point method. First the size of the database for this research study indicates a geometric increase in the memory storage required for state spaces with higher resolution cells. Secondly, the complexity of the radar coverage and the minimum number of arcs required to traverse a given path

directly impact the computational time for the generalized dynamic program. These factors are affected by the type and size of the network model.

This research study has validated many of the conclusions from other studies in network modeling. The direct application of the network model results are given as a summary of the advantages and disadvantages in table 5-1.

Table 5-1
SUMMARY OF MODEL ADVANTAGES and DISADVANTAGES

ADVANTAGES	DISADVANTAGES
1. Increased dimensionality of movement directions.	1. Increased computational requirements and processing time.
2. Ability to model user determined features.	2. Increased database memory storage requirements.
3. Higher resolution of radar coverage by encompassing the use of a point-to-point network in a threat cell.	3. Man hours required to build network.
4. Only three criteria were required in the development of nondominated routes.	4. Each criteria required a separate graph thus increasing the computer memory storage requirements.

<u>Network Modeling Recommendations</u> Based on the advantages and disadvantages noted in the research study there are several recommendations for further improvement to the existing state of the research network model. First the

size of the required memory storage can be significantly reduced by incorporating sparse matrices or sparse sets. The database used for the network criteria is not a sparse set. In a sparse matrix only the predecessor and successor node arc values are stored in memory. Application of a sparse set database could reduce the number of nodes for this particular study from 786,432 to 8,448.

Secondly, the point-to-point network memory storage requirements can be decrease by reducing the number of interconnecting arcs between adjacent nodes. Also, elimination of stacked networks to simulate different altitudes would reduce the memory storage requirements. The trade-off for this procedure is the implementation of a lower resolution graph. A lower resolution graph would decrease the allowable directions of movement along the network. A lower resolution graph would also generate routes with a weaker simulation of realistic alternatives.

Generalized DP and Large-Scale Graphs

The application of generalized DP to large-scale networks has several advantages and disadvantages associated with computational times and the solution optimality. The research study has shown that generalized DP required more than three times the number of calculations than conventional DP. This produced a comparatively longer requirement for CPU processing time with generalized DP. In efficient paths with only one or two intermediate nodes the research study also shows that both conventional and generalized DP appear to have little or no difference in objective function values. Thus, the combinatorial increase of possible paths which exist over greater separations between the origin and destination nodes provide conventional DP an access to the optimal path. In smaller grids or when the separation between the origin and destination nodes is less than two nodes, conventional DP is less likely to find an efficient path. However, this may not be the case for nongrid networks (as in a limited highway system). In most cases these network structures would possess a smaller density of adjacent nodes. For these cases the conventional DP would not have the benefit of a grid network's combinatorial increase in paths options between origin and destination.

Secondly, it was observed that the computational time

to determine paths from higher numbered nodes to lower numbered nodes significantly increased with generalized DP. As an automated process, Dijkstra's algorithm searches for efficient paths in a sequential manner starting with the lowest-numbered nodes. The study indicates that when the origin node number is larger than the destination node the computer program requires more CPU time to evaluate the graph.

Recommendations for the Application of Generalized DP to Large-Scale Graphs The tradeoff between the computational requirements of the generalized DP, the consequences of selecting between an optimal and near optimal path and the response time needed for real-time planning are significant criteria in determining the application of this research study methodology. For paths requiring more than two intermediate nodes, generalized DP has been found to require significantly longer computational time with little or no difference between objective function values. This study has shown that conventional DP is a lower bound for the generalized DP method. Additionally, the study also revealed the near-optimal quality of conventional DP for paths with less than three intermediate nodes. Therefore, it is recommended that in large-scale networks, conventional DP should be used to determine efficient paths between nodes that are separated by more

than two intermediate vertices. However, the use of generalized DP is applicable for networks that do not have a grid symmetry or grids that are significantly altered due to man-made or natural terrain. In both cases the combinatorial increase of possible paths from origin to destination is degraded by a limited network.

Recommendations for improvement of the research methodology include considering methods for decreasing the computational requirements in the generalized DP extension of Dijkstra's algorithm. If this is accomplished, then the application of the generalized DP for real-time routing would be applicable to large-scale networks. The refinement of methods to evaluate arc values within the program would greatly reduce computational requirements. Specifically, the application of computer programming techniques to avoid ineffective searches of the memory stored data base are required to decrease the processing time.

Further, based on the symmetry and scale of the network, the "breakpoint" of nonoptimal solutions between the conventional and generalized DP objective function values should be established. This would determine a criteria for deciding which method is applicable to a given problem.

In addition to determining the network requirements for a given methodology, the resolution and scale of the

fixed weights required for generalized DP should be established with analytical techniques. By defining the resolution of the fixed weights the confidence in the nondominated alternatives will be improved. Without predetermining the scale of fixed weights the application of the generalized DP is not guaranteed to generate all possible efficient paths.

Recommendations for the Implementation of Facility Location Problems

The application of spacefilling curve algorithms as a method of incorporating facility locations with routing was beyond the scope of this study. The use of this algorithm will enhance the formulation of specific routing problems. There are a number of applications for the spacefilling curves in the formulation of routing and facility location problems. For situations with multiple areas of interest, the clustering of specific nodes (targets and staging areas) by use of the spacefilling curves would significantly reduce the number of formulations needed to determine efficient routes. The application of spacefilling curves in the model formulation of a multiple depot/tour problem would eliminate any unnecessary examination of inefficient target and staging area combinations.

Additionally, spacefilling curves present the possibility of enhancing this research methodology with the

capability to formulate facility locations. Solutions to this problem would determine optimal locations for staging areas, airborne jammers and FARPS (Forward Arming and Refueling Points) for helicopters.

Summary

The summary of recommendations for further study are given in table 5-2.

Table 5-2
Recommendation For Further Study

MODELING

1. Reduce the database requirements with the application of sparse matrices.

2. Enhance the computational efficiency of the generalized DP extension of Dijkstra's Algorithm.

3. Determine the efficiency of generalized DP versus the conventional form as applied to different types of networks.

MODEL FORMULATION

1. Apply the Spacefilling Curve Algorithm for use in target clustering and facility location problems.

2. Accurately determine the scale and resolution of the fixed weights that are necessary in the generation of efficient paths for multicriteria network routing problems.

APPENDIX 1

FORTRAN77 Computer Program of the
Generalized Dynamic Programming
Extension of Dijkstra's Algorithm

```
************************************************************
*           THE GENERALIZED DP PROGRAM
*
*      THIS PROGRAM USES DIJKSTRA'S ALGORITHM WITH DECISION
*      RULES BASED ON CARRAWAY'S ALGORITHM PUBLISHED IN THE
*      EUROPEAN JOURNAL OF OPERATIONS RESEARCH (VOL.44,
*      NUMBER 1, JAN 5, 1990).
*
*      THIS PROGRAM FINDS THE OPTIMAL EFFICIENT PATH IN A
*      1,2 or 3 CRITERIA STOCHASTIC NETWORK.
*
*
************************************************************
*      VARIABLES:
*
*      A - Stores the Distance Matrix Database.
*      B - Stores the Active Detection Database.
*      RP - Stores the Passive Detection Database.
*      DD - Stores the Distance values of the determined
*           subpath.
*      PB - Stores the Active values of the determined
*           subpath.
*      PR - Stores the Passive values of the determined
*           subpath.
*      DIST - Efficient value of objective function from the
*             undetermined node to the efficient path tree.
*      VO - Starting node.
*      W - Ending node.
*      M - Total number of nodes in the network.
*      X - Distance coefficient (lambda 1 value).
*      YY - Active Detection coefficient (lambda 2 value).
*      Z - Passive Detection coefficient (lambda 3 value).
*
************************************************************
*      BOOKING VARIABLES:
*
*      LENGTH - Length of the subpath.
*      FROM - From determined node.
*      NUNUM - Next node to be determined from in the path.
*      UNDET - List of undetermined nodes.
*      NEXT - Next node to be added to the efficient path
*             tree.
*      TO - To next determined node.
*      EDGES - Current number of edges (arcs) in the
*              efficient path tree.
*      VERTEX - Vertex (node) of partial efficient path tree
*               on the most efficient path from the
*               undetermined
*               node to VO.
*      PLL - Stores the Distance sum (additive).
```

```
*       PKK - Stores the Active Detection sum
*             (multiplicative).
*       PPK - Stores the Passive Detection sum
*             (multiplicative).
*       H - Subroutine exchanged value of A network extrema.
*       HH - Subroutine exchanged value of the B network
*            extrema.
*       HHH - Subroutine exchanged value of the RP network
*             extrema.
*       DTIME - Used to account for computing time.
*       TIMEARRAY- Used to account for computing time.
*       DTIME - Used to account for computing time.
*
*************************************************************
        REAL A(700,700),B(700,700),LENGTH(700),JK,P,DIST(700),T,L,SS
        REAL DD(700),PK(700),PH,D,PB,LL,H,HH,PL
        REAL HHH, RP(700,700), PPK(700), PKK, PLL
        REAL ACOUNT(700), PCOUNT(700), PC, AC, PCC, ACC,DDD(700)
        REAL ACT(700), PCT(700), DT(700), SSS, JFK
        REAL DTIME, TIMEDIFF, TIMEARRAY(20), X, YY, Z
        INTEGER UNDT(700), VERX(700)
        INTEGER M,VO,W,FROM(700),TO(700),Q,R,N,O,Y,U,V,VERT,S,NBR
        INTEGER EDGES,NEXT,NUMUN,UNDET(700),VERTEX(700)
        CHARACTER*20 FILNM, RESULTS, DATA, PROB, PRB, ADATA, PDATA,OPUT
        PRINT*,'ENTER FILE TO SAVE COMPLETE RESULTS.'
        READ(*,'(A20)') RESULTS
        OPEN( UNIT=3, FILE=RESULTS, STATUS='NEW')
        PRINT*,'ENTER FILE TO SAVE PARTIAL RESULTS.'
        READ(*,'(A20)') OPUT
        OPEN( UNIT=11, FILE=OPUT, STATUS='NEW')
*************************************************************
*       READING IN THE DISTANCE, ACTIVE AND PASSIVE FILES.
*************************************************************
        PRINT*,'ENTER DISTANCE FILE NAME'
        READ(*, '(A20)') FILNM
        OPEN( UNIT=2, FILE=FILNM, STATUS='OLD')
        READ(2,*), ((A(O,N),N=1,6),O=1,6)
        READ(2,*) VO
        READ(2,*) W
        READ(2,*) M
        PRINT*,'ENTER ACTIVE DETECT FILE NAME'
        READ(*, '(A20)') PROB
        OPEN( UNIT=4, FILE=PROB, STATUS='OLD')
        READ(4,*), ((B(O,N),N=1,6),O=1,6)
        PRINT*,'ENTER PASSIVE DETECT FILE NAME'
        READ(*, '(A20)') PRB
        OPEN( UNIT=1, FILE=PRB, STATUS='OLD')
        READ(1,*), ((RP(O,N),N=1,6),O=1,6)
        PRINT*,'ENTER THE DISTANCE COEFFICENT'
        READ*,X
```

```
      PRINT*,'ENTER THE ACTIVE DETECT COEFFICENT'
      READ*,YY
      PRINT*,'ENTER THE PASSIVE DETECT COEFFICENT'
      READ*,Z
      PRINT*,'ENTER THE SCENARIO NUMBER'
      READ*,NBR
      PRINT 700, VO
      PRINT 703, W
      PRINT 800, M
      WRITE(3,*) '                                 '
      WRITE(3,*) '                                 '
      WRITE(3,*) '                                 '
      WRITE(3,*) '                THE EFFICENT ROUTING OUTPUT FOR  '
      WRITE(3,*) '                       SCENARIO NUMBER ',NBR
      WRITE(3,*) '                                 '
      WRITE(3,*) '                                 '
      WRITE(3,*) '                                 '
      WRITE (3,700) VO
      WRITE (3,703) W
      WRITE (3,800) M
      WRITE(3,704) X
      WRITE(3,70) YY
      WRITE(3,706) Z
      WRITE(11,*) '                                 '
      WRITE(11,*) '                                 '
      WRITE(11,*) '                                 '
      WRITE(11,*) '               THE EFFICENT ROUTING OUTPUT FOR '
      WRITE(11,*) '                      SCENARIO NUMBER ',NBR
      WRITE(11,*) '                                 '
      WRITE(11,*) '                                 '
      WRITE(11,*) '                                 '
      WRITE (11,700) VO
      WRITE (11,703) W
      WRITE (11,800) M
      WRITE(11,704) X
      WRITE(11,70) YY
      WRITE(11,706) Z
***********************************************************************
*     INITALIZING MATRIX VALUES TO INDICATE UNCONNECTED
*     NODES
***********************************************************************
      DO 111 I=1,M
      DO 112 J=1,M
      IF (B(I,J).EQ.900) THEN
      B(I,J)=-900
      ELSE
      B(I,J)=B(I,J)
      END IF
      IF (RP(I,J).EQ.900) THEN
      RP(I,J)=-900
```

```
      ELSE
      RP(I,J)=RP(I,J)
      END IF
112   CONTINUE
111   CONTINUE
      WRITE(3,*) '                                                    '
      WRITE(3,*) '                                                    '
      WRITE(3,*) '                      A * DENOTES A LEAST COST LINK'
      WRITE(3,*) '                                                    '
      WRITE(3,*) '                                                    '
700   FORMAT(12X'THE STARTING NODES IS ',I3,/)
703   FORMAT(12X'THE DESTINATION NODE IS ',I3,/)
800   FORMAT(12X'THE TOTAL NUMBER OF NODES PER NETWORK IS ',I3,//)
704   FORMAT(12X'THE DISTANCE WEIGHTING FACTOR IS ',F6.3)
705   FORMAT(12X'THE ACTIVE DETECTION WEIGHTING FACTOR IS ',F6.3)
706   FORMAT(12X'THE PASSIVE DETECTION WEIGHTING FACTOR IS ',F6.3)
      WRITE(3,*) '                                                    '
      WRITE(3,*) '                                                    '
***********************************************************
*     INITIALIZING VARIABLE IN THE PROGRAM: STARING NODE,
*     ENDING NODE, AND THE DISTANCE, ACTIVE DETECTION,
*     PASSIVE DETECTION VALUES AND OBJECTIVE FUNCTION
*     VALUES FROM VO TO ALL OTHER NETWORK NODES.
***********************************************************
888   EDGES=0
      NEXT=VO
      TIMEDIFF = DTIME( TIMEARRAY )
      NUMUN=M-1
          VERT=NEXT
      DO 100 I=1,M
          UNDET(I)=I
          UNDT(I)=I
          ND(I)=A(VO,I)
          DOD(I)=A(VO,I)
          PPN(I)=RP(VO,I)
          PCOUNT(I)=RP(VO,I)
          PCT(I)=RP(VO,I)
          PK(I)=B(VO,I)
          ACOUNT(I)=B(VO,I)
          ACT(I)=B(VO,I)
       DIST(I)=(X*A(VO,I)+B(VO,I)*YY+Z*RP(VO,I))
       DT(I)=(X*A(VO,I)+B(VO,I)*YY+Z*RP(VO,I))
          VERTEX(I)=VO
          VERX(I)=VERTEX(I)
100   CONTINUE
      UNDET(VO)=M
      DIST(VO)=DIST(M)
      DT(VO)=DT(M)
      GO TO 301
***********************************************************
```

```
*       UPDATING THE EFFICIENT PATH TO EACH UNDETERMINED
*       VERTEX
***********************************************************
200     DO 300 I=1,NUMUN
            J=UNDET(I)
        IF(A(NEXT,J).GT.100) THEN
            GO TO 300
            ELSE
            PB=(B(NEXT,J))*PH
            AC=(B(NEXT,J))*ACC
            D=A(NEXT,J)+LL
            PKK=(RP(NEXT,J))*PHH
            PC=(RP(NEXT,J))*PCC
            VERT=NEXT
***********************************************************
*        CALLING THE SUBROUTINES TO DETERMINE THE EXTREMA FOR
*        EACH OF THE THREE CRITERIA NETWORKS.
*        LONGPK - DISTANCE CRITERIA NETWORK EVALUATION
*        SHORTPK - ACTIVE DETECTION CRITERIA EVALUATION
*        PASSPK - PASSIVE DETECTION CRITERIA EVALUATION
***********************************************************
        CALL LONGPK (A,VERT,M,W,HH,DDD,UNDT,VERX)
        CALL SHORTPK (B,VERT,M,W,H,ACT,UNDT,VERX,A)
        CALL PASSPK (RP,VERT,M,W,HHH,PCT,UNDT,VERX,A)
            L=(D+HH)
            PL=(H*PB)
            PLL=(HHH*PKK)
            JK=X*L+PL*YY+Z*PLL
            JFK=X*D+AC*YY+Z*PC
***********************************************************
*       PICKING THE MOST EFFICENT SUB PATH TO THE
*       UNDETERMINED
*       NODE FROM THE DETERMINED NODE.
***********************************************************
                IF ((DIST(I).GE.JK)) THEN
        GO TO 300
        ELSE
            VERTEX(I)=NEXT
            PK(I)=PB
            PPK(I)=PKK
            DD(I)=D
            DIST(I)=JK
            DT(I)=JFK
            ACOUNT(I)=AC
            PCOUNT(I)=PC
        END IF
        END IF
300     CONTINUE
301     K=1
```

```
      ACC=ACOUNT(1)
      PCC=PCOUNT(1)
      LL=DD(1)
      PH=PK(1)
      PHH=PPK(1)
      SS=DIST(1)
      SSS=DT(1)
      DO 400 I=1,NUMUN
************************************************************
*     PICKING AN EFFICENT PATH TO AN UNDETERMINED VERTEX.
************************************************************
      IF(DIST(I).LE.SS) THEN
            GO TO 400
         ELSE
            SS=DIST(I)
            SSS=DT(I)
            LL=DD(I)
            PH=PK(I)
            PHH=PPK(I)
            ACC=ACOUNT(I)
            PCC=PCOUNT(I)
            K=I
      END IF
400   CONTINUE
************************************************************
*     ADD EDGE TO EFFICIENT PATH TREE
************************************************************
402   EDGES=EDGES+1
      FROM(EDGES)=VERTEX(K)
      TO(EDGES)=UNDET(K)
      LENGTH(EDGES)=SSS
600   FORMAT(13X'FROM NODE ',I3,' TO ',I3,' WITH TOTAL LENGTH '
      WRITE(3,600) FROM(EDGES), TO(EDGES),  LENGTH(EDGES)
      NEXT=UNDET(K)
************************************************************
*     CHECKING TO SEE IF THE ENDING NODE HAS BEEN REACHED
************************************************************
      IF (NEXT.EQ.W) THEN
************************************************************
*     REPORTING THE COMPUTING TIME AND CHARACTERISITICS OF
*     THE EFFICIENT PATH - DISTANCE AND ACTIVE AND PASSIVE
*     PROBABILITIES.
************************************************************
      TIMEDIFF = DTIME( TIMEARRAY )
      WRITE(3,*) '                                  '
      WRITE(3,*) '          Total computing time =',TIMEDIFF
      WRITE(3,*) '                                  '
      WRITE(3,*) '          Total distance = ',LL
      WRITE(3,*) '      The active detection expected value = ',ACC
      WRITE(3,*) '      The passive detection expected value = ',PCC
```

```
      WRITE(3,*) '                                  '
      WRITE(3,*) '                                  '
      WRITE(11,*) '                                 '
      WRITE(11,*) '         Total computing time =',TIMEDIFF
      WRITE(11,*) '                                 '
      WRITE(11,*) '         Total distance = ',LL
      WRITE(11,*) '      The active detection expected value = ',ACC
      WRITE(11,*) '      The passive detection expected value = ',PCC
      WRITE(11,*) '                                 '
      WRITE(11,*) '                                 '
      GO TO 500
      ELSE
************************************************************
*     DELETING ANY NEWLY DETERMINED NODES FROM THE
*     UNDETERMINED LIST.
************************************************************
      DIST(K)=DIST(NUMUN)
      DT(K)=DT(NUMUN)
      UNDET(K)=UNDET(NUMUN)
      DD(K)=DD(NUMUN)
      PPK(K)=PPK(NUMUN)
      PK(K)=PK(NUMUN)
      ACOUNT(K)=ACOUNT(NUMUN)
      PCOUNT(K)=PCOUNT(NUMUN)
      VERTEX(K)=VERTEX(NUMUN)
************************************************************
*     CHECKING FOR ANY MORE UNDETERMINED VERTICES FOR
*     EVALUATION.
************************************************************
      NUMUN=NUMUN-1
      GO TO 200
      END IF
************************************************************
*     SUBROUTINE TO FIND THE DISTANCE EXTREMA.
************************************************************
      SUBROUTINE LONGPK (BB,VERT,M,W,HH,DIS,UND,VER)
      REAL BB(700,700),JK,DIS(700),HH
      INTEGER NEXT,NUMUN,UND(700),VER(700),M,W,VERT
      NEXT=VERT
      NUMUN=M-1
120   CONTINUE
      UND(VERT)=M
      DIS(VERT)=DIS(M)
      GO TO 30
200   DO 300 I=1,NUMUN
          J=UND(I)
      IF (BB(NEXT,J).GT.100) THEN
      GO TO 300
      ELSE
          JK=BB(NEXT,J)+HH
```

```
      IF ((DIS(I).LE.JK)) THEN
      GO TO 300
      ELSE
          VER(I)=NEXT
          DIS(I)=JK
      END IF
      END IF
300   CONTINUE
30    K=1
      HH=DIS(1)
      DO 400 I=1,NUMUN
          IF (DIS(I).GE.HH) THEN
          GO TO 400
          ELSE
              HH=DIS(I)
              K=I
      END IF
400   CONTINUE
      NEXT=UND(K)
      IF (NEXT.EQ.W) THEN
      RETURN
      ELSE
      DIS(K)=DIS(NUMUN)
      UND(K)=UND(NUMUN)
      VER(K)=VER(NUMUN)
      NUMUN=NUMUN-1
      GO TO 200
      END IF
      STOP
      END
*************************************************************
*     SUBROUTINE TO FIND THE ACTIVE DETECTION EXTERMA.
*************************************************************
      SUBROUTINE SHORTPK (CC,VERT,M,W,H,DIS,UT,VT,AA)
      REAL JK,DIS(700),H,CC(700,700),AA(700,700)
      INTEGER NEXT,NUMUN,UT(700),VT(700),M,W,VERT
      NEXT=VERT
      NUMUN=M-1
140   CONTINUE
      UT(VERT)=M
      DIS(VERT)=DIS(M)
      GO TO 30
200   DO 300 I=1,NUMUN
          J=UT(I)
      IF (CC(NEXT,J).GT.100) THEN
      GO TO 300
      ELSE
          JK=CC(NEXT,J)*H
      IF ((DIS(I).GE.JK)) THEN
      GO TO 300
```

```
      ELSE
          VT(I)=NEXT
          DIS(I)=JK
      END IF
      END IF
300   CONTINUE
30   K=1
      H=DIS(1)
      DO 400 I=1,NUMUN
          IF (DIS(I).LE.H) THEN
          GO TO 400
          ELSE
              H=DIS(I)
              K=I
      END IF
400   CONTINUE
      NEXT=UT(K)
      IF (NEXT.EQ.W) THEN
      RETURN
      ELSE
      DIS(K)=DIS(NUMUN)
      UT(K)=UT(NUMUN)
      VT(K)=VT(NUMUN)
      NUMUN=NUMUN-1
      GO TO 200
      END IF
      STOP
      END
*************************************************************
*     SUBROUTINE TO FIND THE PASSIVE DETECTION EXTREMA.
*************************************************************
      SUBROUTINE PASSPK (C,VERT,M,W,HHH,DIS,UN,VX,AA)
      REAL JK,DIS(700),HHH,C(700,700),AA(700,700)
      INTEGER NEXT,NUMUN,UN(700),VX(700),M,W,VERT
      NEXT=VERT
      NUMUN=M-1
      UN(VERT)=M
      DIS(VERT)=DIS(M)
      GO TO 30
200   DO 300 I=1,NUMUN
          J=UN(I)
      IF (C(NEXT,J).GT.100) THEN
      GO TO 300
      ELSE
          JK=C(NEXT,J)*HHH
      IF ((DIS(I).GE.JK)) THEN
      GO TO 300
      ELSE
          VX(I)=NEXT
          DIS(I)=JK
```

```
      END IF
      END IF
300   CONTINUE
30   K=1
      HHH=DIS(1)
      DO 400 I=1,NUMUN
      IF (DIS(I).LE.HHH) THEN
          GO TO 400
          ELSE
              HHH=DIS(I)
              K=I
      END IF
400   CONTINUE
      NEXT=UN(K)
      IF (NEXT.EQ.W) THEN
      RETURN
      ELSE
      DIS(K)=DIS(NUMUN)
      UN(K)=UN(NUMUN)
      VX(K)=VX(NUMUN)
      NUMUN=NUMUN-1
      GO TO 200
      END IF
      STOP
      END
```

APPENDIX 2

FORTRAN 77 Computer Program of the Conventional Dynamic Programming Extension of Dijkstra's Algorithm

```
***********************************************************
*       THE CONVENTIONAL DP PROGRAM
*
*       THIS PROGRAM USES DIJKSTRA'S ALGORITHM WITH DECISION
*       RULES BASED ON CONVENTIONAL DP.
*
*
***********************************************************
*
*       VARIABLES:
*
*       A - Stores the Distance Matrix Database.
*       B - Stores the Active Detection Database.
*       RP - Stores the Passive Detection Database.
*       DD - Stores the Distance values of the determined
*            subpath.
*       PB - Stores the Active values of the determined
*            subpath.
*       PR - Stores the Passive values of the determined
*            subpath.
*       DIST - Efficent value of objective function from the
*              undetermined node to the efficient path tree.
*       VO - Starting node.
*       W - Ending node.
*       M - Total number of nodes in the network.
*       X - Distance coefficient (lambda 1 value).
*       YY - Active Detection coefficient (lambda 2 value).
*       Z - Passive Detection coefficient (lambda 3 value).
*
***********************************************************
*
*       BOOKING VARIABLES:
*
*       LENGTH - Length of the subpath.
*       FROM - From determined node.
*       NUNUM - Next node to be determined from in the path.
*       UNDET - List of undetermined nodes.
*       NEXT - Next node to be added to the efficent path
*              tree.
*       TO - To next determined node.
*       EDGES - Current number of edges (arcs) in the
*               efficent path tree.
*       VERTEX - Vertex (node) of partial efficient path tree
*                on the most efficient path from the
*                undetermined
*                node to VO.
*       PLL - Stores the Distance sum (additive).
*       PKK - Stores the Active Detection sum
*             (multiplicative).
*       PPK - Stores the Passive Detection sum
```

```
*            (multiplicative).
*       H - Subroutine exchanged value of A network extrema.
*       HH - Subroutine exchanged value of the B network
*            extrema.
*       HHH - Subroutine exchanged value of the RP network
*             extrema.
*       DTIME - Used to account for computing time.
*       TIMEARRAY- Used to account for computing time.
*       DTIME - Used to account for computing time.
*
*************************************************************
      REAL A(700,700),B(700,700),LENGTH(700),JK,P,DIST(700),T
      REAL DD(700),G,PK(700),PH,D,PB,LL
      REAL RP(700,700), PPK(700), PKK
      REAL ACOUNT(700), PCOUNT(700), PC, AC, PCC, ACC
      REAL DTIME, TIMEDIFF, TIMEARRAY(20), X, YY, Z
      INTEGER M,VO,W,FROM(700),TO(700),Q,R,N,O,Y,U,V,S,NBR
      INTEGER EDGES,NEXT,NUMUN,UNDET(700),VERTEX(700)
      CHARACTER*20 FILNM, RESULTS, DATA, PROB, PRB, ADATA, PDATA,OPUT
      PRINT*,'ENTER FILE TO SAVE COMPLETE RESULTS.'
      READ(*,'(A20)') RESULTS
      OPEN( UNIT=3, FILE=RESULTS, STATUS='NEW')
      PRINT*,'ENTER FILE TO SAVE PARTIAL RESULTS.'
      READ(*,'(A20)') OPUT
      OPEN( UNIT=11, FILE=OPUT, STATUS='NEW')
*************************************************************
*       READING IN THE DISTANCE, ACTIVE AND PASSIVE FILES.
*************************************************************
      PRINT*,'ENTER DISTANCE FILE NAME'
      READ(*, '(A20)') FILNM
      OPEN( UNIT=2, FILE=FILNM, STATUS='OLD')
      READ(2,*), ((A(O,N),N=1,6),O=1,6)
      READ(2,*) VO
      READ(2,*) W
      READ(2,*) M
      PRINT*,'ENTER ACTIVE DETECT FILE NAME'
      READ(*, '(A20)') PROB
      OPEN( UNIT=4, FILE=PROB, STATUS='OLD')
      READ(4,*), ((B(O,N),N=1,6),O=1,6)
      PRINT*,'ENTER PASSIVE DETECT FILE NAME'
      READ(*, '(A20)') PRB
      OPEN( UNIT=1, FILE=PRB, STATUS='OLD')
      READ(1,*), ((RP(O,N),N=1,6),O=1,6)
      PRINT*,'ENTER THE DISTANCE COEFFICENT'
      READ*,X
      PRINT*,'ENTER THE ACTIVE DETECT COEFFICENT'
      READ*,YY
      PRINT*,'ENTER THE PASSIVE DETECT COEFFICENT'
      READ*,Z
      PRINT*,'ENTER THE SCENARIO NUMBER'
```

```
      READ*,NBR
      PRINT 700, VO
      PRINT 703, W
      PRINT 800, M
      WRITE(3,*) '                                  '
      WRITE(3,*) '                                  '
      WRITE(3,*) '                                  '
      WRITE(3,*) '                THE EFFICENT ROUTING OUTPUT FOR  '
      WRITE(3,*) '                      SCENARIO NUMBER ',NBR
      WRITE(3,*) '                                  '
      WRITE(3,*) '                                  '
      WRITE(3,*) '                                  '
      WRITE (3,700) VO
      WRITE (3,703) W
      WRITE (3,800) M
      WRITE(3,704) X
      WRITE(3,705) YY
      WRITE(3,706) Z
      WRITE(11,*) '                                  '
      WRITE(11,*) '                                  '
      WRITE(11,*) '                                  '
      WRITE(11,*) '               THE EFFICENT ROUTING OUTPUT FOR '
      WRITE(11,*) '                     SCENARIO NUMBER ',NBR
      WRITE(11,*) '                                  '
      WRITE(11,*) '                                  '
      WRITE(11,*) '                                  '
      WRITE (11,700) VO
      WRITE (11,703) W
      WRITE (11,800) M
      WRITE(11,704) X
      WRITE(11,705) YY
      WRITE(11,706) Z
*****************************************************************
*     INITALIZING MATRIX VALUES TO INDICATE UNCONNECTED
*     NODES
*****************************************************************
      DO 111 I=1,M
      DO 112 J=1,M
      IF (B(I,J).EQ.900) THEN
      B(I,J)=-900
      END IF
      IF (RP(I,J).EQ.900) THEN
      RP(I,J)=-900
      END IF
112   CONTINUE
111   CONTINUE
      WRITE(3,*) '                                  '
      WRITE(3,*) '                                  '
      WRITE(3,*) '             A * DENOTES A LEAST COST LINK'
      WRITE(3,*) '                                  '
```

```
      WRITE(3,*) '                                              '
700   FORMAT(12X'THE STARTING NODES IS ',I3,/)
703   FORMAT(12X'THE DESTINATION NODE IS ',I3,/)
800   FORMAT(12X'THE TOTAL NUMBER OF NODES PER NETWORK IS ',I3,//)
704   FORMAT(12X'THE DISTANCE WEIGHTING FACTOR IS ',F6.3)
705   FORMAT(12X'THE ACTIVE DETECTION WEIGHTING FACTOR IS ',F6.3)
706   FORMAT(12X'THE PASSIVE DETECTION WEIGHTING FACTOR IS ',F6.3)
      WRITE(3,*) '                                              '
      WRITE(3,*) '                                              '
*************************************************************
*     INITIALIZING VARIABLE IN THE PROGRAM: STARING NODE,
*     ENDING NODE,
*     AND THE DISTANCE, ACTIVE DETECTION, PASSIVE DETECTION
*     VALUES AND OBJECTIVE FUNCTION VALUES FROM VO TO ALL
*     OTHER NETWORK NODES.
*************************************************************
888   EDGES=0
      NEXT=VO
      TIMEDIFF = DTIME( TIMEARRAY )
      NUMUN=M-1
      DO 100 I=1,M
          UNDET(I)=I
          DD(I)=A(VO,I)
          PPK(I)=RP(VO,I)
          PCOUNT(I)=PPK(I)
          PK(I)=B(VO,I)
          ACOUNT(I)=PK(I)
          DIST(I)=(X*A(VO,I))+(B(VO,I)*YY)+(Z*RP(VO,I))
          VERTEX(I)=VO
100   CONTINUE
      UNDET(VO)=M
      DIST(VO)=DIST(M)
      DD(VO)=DD(M)
      PPK(VO)=PPK(M)
      PK(VO)=PK(M)
      ACOUNT(VO)=ACOUNT(M)
      PCOUNT(VO)=PCOUNT(M)
      GO TO 350
200   DO 300 I=1,NUMUN
          J=UNDET(I)
          D=A(NEXT,J)+LL
          PB=B(NEXT,J)*PH
          AC=B(NEXT,J)*ACC
          PKK=RP(NEXT,J)*PHH
          PC=RP(NEXT,J)*PCC
          JK=(X*D)+(AC*YY)+(Z*PC)
*************************************************************
*     PICKING THE MOST EFFICIENT SUBPATH TO THE
*     UNDETERMINED NODE FROM THE DETERMINED NODE.
*************************************************************
```

```
      IF (DIST(I).GE.JK) THEN
      GO TO 300
      ELSE
          VERTEX(I)=NEXT
          PK(I)=PB
          PPK(I)=PKK
          ACOUNT(I)=AC
          PCOUNT(I)=PC
          DD(I)=D
          DIST(I)=JK
      END IF
300   CONTINUE
350   K=1
      G=DIST(1)
      LL=DD(1)
      PH=PK(1)
      PHH=PPK(1)
      ACC=ACOUNT(1)
      PCC=PCOUNT(1)
      DO 400 I=1,NUMUN
************************************************************
*     PICKING AN EFFICENT PATH TO AN UNDETERMINED VERTEX.
************************************************************
          IF (DIST(I).LE.G) THEN
          GO TO 400
          ELSE
              LL=DD(I)
              PH=PK(I)
              PHH=PPK(I)
              ACC=ACOUNT(I)
              PCC=PCOUNT(I)
              G=DIST(I)
              K=I
      END IF
400   CONTINUE
************************************************************
*     ADD EDGE TO EFFICIENT PATH TREE
************************************************************
      EDGES=EDGES+1
      FROM(EDGES)=VERTEX(K)
      TO(EDGES)=UNDET(K)
      LENGTH(EDGES)=G
600   FORMAT(13X'FROM NODE ',I3,' TO ',I3,' WITH TOTAL LENGTH ',
F10.2)
      WRITE(3,600) FROM(EDGES), TO(EDGES),  LENGTH(EDGES)
      NEXT=UNDET(K)
************************************************************
*     CHECKING TO SEE IF THE ENDING NODE HAS BEEN REACHED
************************************************************
      IF (NEXT.EQ.W) THEN
```

```
*************************************************************
*      REPORTING THE COMPUTING TIME AND CHARACTERISITICS OF
*      THE EFFICIENT PATH - DISTANCE AND ACTIVE AND PASSIVE
*      PROBABILITIES.
*************************************************************
       TIMEDIFF = DTIME( TIMEARRAY )
       WRITE(3,*) '                                 '
       WRITE(3,*) '           Total computing time =',TIMEDIFF
       WRITE(3,*) '                                 '
       WRITE(3,*) '           OBJ Function = ',G
       WRITE(3,*) '                                 '
       WRITE(3,*) '           Total distance = ',LL
       WRITE(3,*) '           Total active detection level = ',ACC
       WRITE(3,*) '           Total passive detection level = ',PCC
       WRITE(3,*) '                                 '
       WRITE(3,*) '                                 '
       WRITE(11,*) '                                '
       WRITE(11,*) '          Total computing time =',TIMEDIFF
       WRITE(11,*) '                                '
       WRITE(11,*) '          OBJ Function = ',G
       WRITE(11,*) '                                '
       WRITE(11,*) '          Total distance = ',LL
       WRITE(11,*) '          Total active detection level = ',ACC
       WRITE(11,*) '          Total passive detection level = ',PCC
       WRITE(11,*) '                                '
       WRITE(11,*) '                                '
       GO TO 500
       ELSE
*************************************************************
*      DELETING ANY NEWLY DETERMINED NODES FROM THE
*      UNDETERMINED LIST.
*************************************************************
       DIST(K)=DIST(NUMUN)
       UNDET(K)=UNDET(NUMUN)
       DD(K)=DD(NUMUN)
       PPK(K)=PPK(NUMUN)
       PK(K)=PK(NUMUN)
       ACOUNT(K)=ACOUNT(NUMUN)
       PCOUNT(K)=PCOUNT(NUMUN)
       VERTEX(K)=VERTEX(NUMUN)
*************************************************************
*      CHECKING FOR ANY MORE UNDETERMINED VERTICES FOR
*      EVALUATION.
*************************************************************
       NUMUN=NUMUN-1
       GO TO 200
       END IF
```

APPENDIX 3

d_{ij} / p_{ij} / a_{ij} Matrices of Pairwise Comparisons with the Generalized Dynamic Programming Extension of Dijkstra's Algorithm

SCENARIO 1

d_{ij} / p_{ij} / a_{ij} *MATRICES*

$(\lambda_1,\lambda_2,\lambda_3) = (1,0,0)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.5	37.9	47.7
SALEM AIRFIELD	37.8		6.6	10.2
LOGISTICAL ROUTE	42.2	6.6		7.8
COMMAND & CONTROL	50.0	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		11.87	16.56	22.37
SALEM AIRFIELD	3.80		4.92	7.67
LOGISTICAL ROUTE	15.71	4.92		5.81
COMMAND & CONTROL	21.52	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.590	0.0	.412
SALEM AIRFIELD	.650		0.0	0.0
LOGISTICAL ROUTE	0.0	0.0		0.0
COMMAND & CONTROL	.416	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (0,1,0)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		75.5	62.9	101.9
SALEM AIRFIELD	57.2		10.2	57.6
LOGISTICAL ROUTE	61.7	10.2		10.2
COMMAND & CONTROL	112.7	57.6	10.2	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		31.29	26.18	27.93
SALEM AIRFIELD	16.07		23.17	43.28
LOGISTICAL ROUTE	19.42	23.17		23.17
COMMAND & CONTROL	46.00	43.28	23.17	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	0.0	0.0
SALEM AIRFIELD	0.0		0.0	0.0
LOGISTICAL ROUTE	0.0	0.0		0.0
COMMAND & CONTROL	0.0	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (0,0,1)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		81.1	88.4	81.2
SALEM AIRFIELD	100.5		6.6	37.4
LOGISTICAL ROUTE	92.1	6.6		7.8
COMMAND & CONTROL	90.7	54.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.26	2.96
SALEM AIRFIELD	4.08		4.92	2.46
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	4.92	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		1.44	1.20	.702
SALEM AIRFIELD	.803		0.0	0.0
LOGISTICAL ROUTE	.650	0.0		0.0
COMMAND & CONTROL	.650	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (.333, .333, .333)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	42.2	50.1
SALEM AIRFIELD	37.9		6.6	10.2
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	50.2	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	8.52	6.26
SALEM AIRFIELD	4.08		4.92	7.60
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	8.56	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.416	.820
SALEM AIRFIELD	.599		0.0	0.0
LOGISTICAL ROUTE	.416	0.0		0.0
COMMAND & CONTROL	.778	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (.5, .25, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	40.4	50.1
SALEM AIRFIELD	37.9		6.6	10.2
LOGISTICAL ROUTE	40.4	6.6		7.8
COMMAND & CONTROL	48.2	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	10.72	6.26
SALEM AIRFIELD	4.08		4.92	7.60
LOGISTICAL ROUTE	10.79	4.92		5.81
COMMAND & CONTROL	11.40	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.416	.830
SALEM AIRFIELD	.599		0.0	0.0
LOGISTICAL ROUTE	.416	0.0		0.0
COMMAND & CONTROL	.778	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .5, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	42.2	50.1
SALEM AIRFIELD	37.8		6.6	10.2
LOGISTICAL ROUTE	42.2	6.6		7.8
COMMAND & CONTROL	50.1	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	8.52	6.26
SALEM AIRFIELD	4.08		4.92	7.60
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	8.56	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.416	.828
SALEM AIRFIELD	.599		0.0	0.0
LOGISTICAL ROUTE	.416	0.0		0.0
COMMAND & CONTROL	.778	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .25, .5)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.4	52.2
SALEM AIRFIELD	44.6		6.6	10.2
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	54.8	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.26	4.92
SALEM AIRFIELD	0.0		4.92	7.60
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	4.92	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	.416	.828
SALEM AIRFIELD	.599		0.0	0.0
LOGISTICAL ROUTE	.416	0.0		0.0
COMMAND & CONTROL	.778	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .375, .375)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.4	50.1
SALEM AIRFIELD	37.8		6.6	10.2
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	54.8	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.26	6.26
SALEM AIRFIELD	4.08		4.92	7.60
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	4.92	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.476	.828
SALEM AIRFIELD	.599		0.0	0.0
LOGISTICAL ROUTE	.416	0.0		0.0
COMMAND & CONTROL	.705	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (.375, .25, .375)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	42.2	50.1
SALEM AIRFIELD	37.9		6.6	10.2
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	50.2	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	8.52	5.26
SALEM AIRFIELD	4.08		4.92	7.60
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	8.56	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	.416	.828
SALEM AIRFIELD	.599		0.0	0.0
LOGISTICAL ROUTE	.416	0.0		0.0
COMMAND & CONTROL	.778	0.0	0.0	

$(\lambda_1, \lambda_2, \lambda_3) = (.375, .375, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	40.3	50.1
SALEM AIRFIELD	37.9		6.6	10.2
LOGISTICAL ROUTE	40.4	6.6		7.8
COMMAND & CONTROL	48.2	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	10.72	6.26
SALEM AIRFIELD	4.08		4.92	7.60
LOGISTICAL ROUTE	10.79	4.92		5.81
COMMAND & CONTROL	11.39	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.476	.828
SALEM AIRFIELD	.599		0.0	0.0
LOGISTICAL ROUTE	.476	0.0		0.0
COMMAND & CONTROL	.416	0.0	0.0	

SCENARIO 2

d_{ij} / p_{ij} / a_{ij} MATRICES

$(\lambda_1, \lambda_2, \lambda_3) = (1,0,0)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.5	37.9	47.7
SALEM AIRFIELD	37.8		6.6	10.2
LOGISTICAL ROUTE	42.2	6.6		7.8
COMMAND & CONTROL	50.0	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		11.87	16.56	22.37
SALEM AIRFIELD	3.80		4.92	7.67
LOGISTICAL ROUTE	15.71	4.92		5.81
COMMAND & CONTROL	21.52	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.590	.233	2.19
SALEM AIRFIELD	.650		.302	1.60
LOGISTICAL ROUTE	.233	.302		2.09
COMMAND & CONTROL	2.59	1.60	2.09	

$(\lambda_1, \lambda_2, \lambda_3) = (0,1,0)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		70.7	61.2	75.2
SALEM AIRFIELD	59.1		20.4	10.3
LOGISTICAL ROUTE	63.6	20.4		10.3
COMMAND & CONTROL	61.4	10.3	10.3	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.80	34.30	42.02
SALEM AIRFIELD	28.81		15.77	7.67
LOGISTICAL ROUTE	34.33	15.20		7.67
COMMAND & CONTROL	32.69	7.67	7.67	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	0.0	.966
SALEM AIRFIELD	0.0		0.0	.966
LOGISTICAL ROUTE	0.0	0.0		.966
COMMAND & CONTROL	1.10	.975	.975	

$(\lambda_1, \lambda_2, \lambda_3) = (0,0,1)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		81.1	88.4	81.2
SALEM AIRFIELD	100.5		6.6	37.4
LOGISTICAL ROUTE	92.1	6.6		7.8
COMMAND & CONTROL	90.7	54.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.26	2.96
SALEM AIRFIELD	4.08		4.92	2.46
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	4.92	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		10.14	10.44	21.71
SALEM AIRFIELD	3.90		.302	2.00
LOGISTICAL ROUTE	4.47	.302		2.09
COMMAND & CONTROL	2.15	3.18	2.09	

$(\lambda_1, \lambda_2, \lambda_3) = (.333, .333, .333)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	42.2	50.2
SALEM AIRFIELD	40.3		6.6	10.3
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	50.3	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	8.52	6.33
SALEM AIRFIELD	0.0		4.92	7.67
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	8.64	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.650	1.71
SALEM AIRFIELD	.850		.302	.966
LOGISTICAL ROUTE	.650	.302		2.09
COMMAND & CONTROL	1.67	.975	2.09	

$(\lambda_1,\lambda_2,\lambda_3) = (.5,.25,.25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	40.3	50.2
SALEM AIRFIELD	40.3		6.6	10.3
LOGISTICAL ROUTE	40.4	6.6		7.8
COMMAND & CONTROL	48.2	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	10.72	6.33
SALEM AIRFIELD	4.08		4.92	7.67
LOGISTICAL ROUTE	10.79	4.92		5.81
COMMAND & CONTROL	11.75	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.709	1.71
SALEM AIRFIELD	.599		.302	.966
LOGISTICAL ROUTE	.713	.302		2.09
COMMAND & CONTROL	1.57	.975	.209	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .5, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	42.2	50.2
SALEM AIRFIELD	40.3		6.6	10.3
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	50.3	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	8.52	6.33
SALEM AIRFIELD	0.0		4.92	7.67
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	8.64	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.650	1.71
SALEM AIRFIELD	.709		.302	.966
LOGISTICAL ROUTE	.650	.302		2.09
COMMAND & CONTROL	1.67	.975	2.09	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .25, .5)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.4	50.2
SALEM AIRFIELD	40.3		6.6	10.3
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	52.7	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.26	6.33
SALEM AIRFIELD	0.0		4.92	7.67
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	6.33	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.801	1.71
SALEM AIRFIELD	.709		.302	.966
LOGISTICAL ROUTE	.650	.302		2.09
COMMAND & CONTROL	1.78	.975	2.09	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .375, .375)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.4	50.2
SALEM AIRFIELD	40.3		6.6	10.3
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	52.7	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.26	6.33
SALEM AIRFIELD	0.0		4.92	7.67
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	6.33	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.850	.828
SALEM AIRFIELD	.709		.302	.966
LOGISTICAL ROUTE	.650	.302		2.09
COMMAND & CONTROL	1.78	.975	2.09	

$(\lambda_1, \lambda_2, \lambda_3) = (.375, .25, .375)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	42.2	50.2
SALEM AIRFIELD	37.9		6.6	10.3
LOGISTICAL ROUTE	42.3	6.6		7.8
COMMAND & CONTROL	50.3	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	8.51	6.26
SALEM AIRFIELD	0.0		4.92	7.60
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	8.64	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.650	1.77
SALEM AIRFIELD	.709		.302	.966
LOGISTICAL ROUTE	.650	.302		2.09
COMMAND & CONTROL	1.67	.975	2.09	

$(\lambda_1, \lambda_2, \lambda_3) = (.375, .375, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	40.3	50.2
SALEM AIRFIELD	37.9		6.6	10.3
LOGISTICAL ROUTE	40.4	6.6		7.8
COMMAND & CONTROL	48.2	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	10.72	6.33
SALEM AIRFIELD	0.0		4.92	7.67
LOGISTICAL ROUTE	10.79	4.92		5.81
COMMAND & CONTROL	11.75	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		.650	.709	1.71
SALEM AIRFIELD	.599		.302	.966
LOGISTICAL ROUTE	.714	.302		2.09
COMMAND & CONTROL	1.57	.975	2.09	

SCENARIO 3

d_{ij} / p_{ij} / a_{ij} MATRICES

$(\lambda_1, \lambda_2, \lambda_3) = (1,0,0)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.5	37.9	47.7
SALEM AIRFIELD	37.8		6.6	10.2
LOGISTICAL ROUTE	42.2	6.6		7.8
COMMAND & CONTROL	50.0	10.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		11.87	16.56	22.37
SALEM AIRFIELD	3.80		4.92	7.67
LOGISTICAL ROUTE	15.71	4.92		5.81
COMMAND & CONTROL	21.52	7.67	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.00	2.72	7.16
SALEM AIRFIELD	3.45		2.93	4.53
LOGISTICAL ROUTE	5.02	2.93		4.63
COMMAND & CONTROL	9.66	4.53	4.63	

$(\lambda_1, \lambda_2, \lambda_3) = (0,1,0)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		54.7	39.9	65.1
SALEM AIRFIELD	79.7		10.3	10.3
LOGISTICAL ROUTE	77.9	10.3		10.3
COMMAND & CONTROL	67.2	10.3	10.3	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		14.27	16.56	21.32
SALEM AIRFIELD	41.20		7.67	7.67
LOGISTICAL ROUTE	34.55	7.67		7.67
COMMAND & CONTROL	6.50	7.67	7.67	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		2.09	2.72	4.82
SALEM AIRFIELD	2.87		2.76	3.65
LOGISTICAL ROUTE	3.40	2.76		3.65
COMMAND & CONTROL	5.87	3.67	3.67	

$(\lambda_1, \lambda_2, \lambda_3) = (0,0,1)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		81.1	88.4	81.2
SALEM AIRFIELD	100.5		6.6	37.4
LOGISTICAL ROUTE	92.1	6.6		7.8
COMMAND & CONTROL	90.7	54.2	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.26	2.96
SALEM AIRFIELD	4.08		4.92	2.46
LOGISTICAL ROUTE	8.56	4.92		5.81
COMMAND & CONTROL	4.92	7.60	5.81	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		14.26	18.70	21.71
SALEM AIRFIELD	13.19		2.92	11.68
LOGISTICAL ROUTE	17.01	2.93		4.63
COMMAND & CONTROL	16.33	11.68	4.63	

$(\lambda_1, \lambda_2, \lambda_3) = (.333, .333, .333)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.5	50.3
SALEM AIRFIELD	37.9		6.6	10.2
LOGISTICAL ROUTE	42.4	6.6		7.8
COMMAND & CONTROL	48.2	10.3	7.9	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.33	7.07
SALEM AIRFIELD	4.08		4.92	7.67
LOGISTICAL ROUTE	8.64	4.92		5.88
COMMAND & CONTROL	11.75	7.67	5.88	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.56	4.62	7.16
SALEM AIRFIELD	4.36		2.93	4.53
LOGISTICAL ROUTE	4.59	2.93		4.63
COMMAND & CONTROL	1.46	3.67	4.02	

$(\lambda_1, \lambda_2, \lambda_3) = (.5, .25, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	40.3	50.2
SALEM AIRFIELD	37.9		6.6	10.3
LOGISTICAL ROUTE	40.4	6.6		7.9
COMMAND & CONTROL	48.2	10.3	7.9	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	10.72	6.33
SALEM AIRFIELD	4.08		4.92	7.67
LOGISTICAL ROUTE	10.79	4.92		5.88
COMMAND & CONTROL	11.75	7.67	5.88	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.56	4.82	6.97
SALEM AIRFIELD	4.36		2.93	3.65
LOGISTICAL ROUTE	4.86	2.93		3.97
COMMAND & CONTROL	6.46	3.67	4.02	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .5, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	40.2	50.3
SALEM AIRFIELD	37.8		6.6	10.3
LOGISTICAL ROUTE	40.3	6.6		7.9
COMMAND & CONTROL	48.2	10.3	7.9	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	8.52	7.07
SALEM AIRFIELD	5.21		4.92	7.67
LOGISTICAL ROUTE	12.29	4.92		5.88
COMMAND & CONTROL	11.75	7.67	5.88	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.56	3.65	6.11
SALEM AIRFIELD	3.45		2.93	3.65
LOGISTICAL ROUTE	3.66	2.93		3.97
COMMAND & CONTROL	6.46	3.67	4.02	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .25, .5)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.5	50.2
SALEM AIRFIELD	37.9		6.6	10.3
LOGISTICAL ROUTE	42.4	6.6		7.9
COMMAND & CONTROL	60.6	10.3	7.9	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.33	6.33
SALEM AIRFIELD	4.08		4.92	7.67
LOGISTICAL ROUTE	8.64	4.92		5.81
COMMAND & CONTROL	2.46	7.67	5.88	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.56	4.62	6.98
SALEM AIRFIELD	4.36		2.93	3.65
LOGISTICAL ROUTE	4.59	2.93		3.97
COMMAND & CONTROL	9.34	3.67	4.02	

$(\lambda_1, \lambda_2, \lambda_3) = (.25, .375, .375)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.5	50.2
SALEM AIRFIELD	37.9		6.6	10.3
LOGISTICAL ROUTE	42.4	6.6		7.9
COMMAND & CONTROL	50.4	10.3	7.8	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.33	6.33
SALEM AIRFIELD	4.08		4.92	7.67
LOGISTICAL ROUTE	8.54	4.92		5.88
COMMAND & CONTROL	9.45	7.67	5.88	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.56	4.62	6.98
SALEM AIRFIELD	4.36		2.93	3.65
LOGISTICAL ROUTE	4.59	2.93		3.97
COMMAND & CONTROL	6.88	3.67	4.02	

$(\lambda_1, \lambda_2, \lambda_3) = (.375, .25, .375)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	44.5	50.2
SALEM AIRFIELD	37.9		6.6	10.3
LOGISTICAL ROUTE	42.4	6.6		7.9
COMMAND & CONTROL	50.3	10.3	7.9	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	6.33	6.33
SALEM AIRFIELD	4.08		4.92	7.67
LOGISTICAL ROUTE	8.64	4.92		5.88
COMMAND & CONTROL	8.64	7.67	5.88	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.56	4.62	6.98
SALEM AIRFIELD	4.36		2.93	3.65
LOGISTICAL ROUTE	4.59	2.93		3.97
COMMAND & CONTROL	7.77	3.67	4.02	

$(\lambda_1, \lambda_2, \lambda_3) = (.375, .375, .25)$

DISTANCE (nautical miles)

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		37.8	40.3	50.2
SALEM AIRFIELD	37.9		6.6	10.3
LOGISTICAL ROUTE	40.4	6.6		7.9
COMMAND & CONTROL	48.2	10.3	7.9	

EXPECTED VALUE OF PASSIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		0.0	12.21	7.07
SALEM AIRFIELD	5.21		4.92	7.67
LOGISTICAL ROUTE	12.29	4.92		5.88
COMMAND & CONTROL	11.75	7.67	5.88	

EXPECTED VALUE OF ACTIVE RADAR DETECTION

NODE TYPE	STAGING AREA	SALEM AIRFIELD	LOGISTICAL ROUTE	COMMAND & CONTROL
STAGING AREA		3.56	4.82	6.11
SALEM AIRFIELD	4.36		2.93	3.65
LOGISTICAL ROUTE	4.86	2.93		3.97
COMMAND & CONTROL	6.46	3.67	4.02	

APPENDIX 4
ADBASE Vehicle Routing Problem Formulation

```
***—****1*********2——————****3*********4****** ADBASE MODE = 0 SECTION
   1. NUMB             1    (NUMBER OF PROBLEMS TO BE SOLVED)
--------------------------------
   2. MODE             1    (REGULAR OR RANDOM PROBLEM MODE) 1,2
--------------------------------
   3. IFASE2           5    (PHASE II OPTION) 1 TO 5
   4. IFASE3           2    (PHASE III OPTION) 0,1,2
   5. IWEAK            0    (EFFICIENT OR WEAKLY-EFFICIENT) 0,1
--------------------------------
   6. MLISTB        2000    (MAXIMUM NUMBER OF EFFICIENT BASES) <2500
   7. IZFMT            4    (EXPONENTIAL/FIXED FORMAT IN ZFILE) 0 TO 6
--------------------------------
   8. IPRINT(1)        1    (OBVIOUS ERRORS) 0,1
   9. IPRINT(2)        0    (PROBLEM COEFFICIENTS) 0,1
  10. IPRINT(3)        5    (NOTHING/BASES/EXTREME PTS) 0/1,2,3/4,5,6
  11. IPRINT(4)        1    (EFFICIENCY TOTALS) 0,1
  12. IPRINT(5)        0    (INDIVIDUAL PROBLEM DATA) 0,1
  13. IPRINT(6)        0    (CUMULATIVE DATA) 0,1
  14. IPRINT(7)        0    (CODE LISTS) 0,1
  15. IPRINT(8)        1    (ZFILE) 0,1
  16. IPRINT(9)        1    (REDUCED COSTS AND TABLEAUS) 0,1,2
  17. IPRINT(10)       0    (LFILE) 0,1
  18. IPRINT(11)       1    (PREMULTIPLICATION T-MATRIX) 0,1
--------------------------------
  19. IV9L             1    (BEGINNING TABLEAU VARIABLE)
  20. IV9U           100    (ENDING TABLEAU VARIABLE)
  21. I9L              1    (TABLEAUS BEGIN AT THIS BASIS)
  22. I9U           9999    (TABLEAUS END AT THIS BASIS)
  23. I10L             0    (LFILE BEGINS ON WAY TO THIS BASIS)
  24. I10U            50    (LFILE ENDS AT THIS BASIS)
***—****1*********2——————****3*********4*********5*** MODE = 2 SECTION
```

```
NAME            SCENARIO 1 LAMBDA SET (1,0,0)
     850        3      12        2      11      14         0       40
       6
  1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.00000  2 10     1.00000
       2
  1        1.00000  2        1.00000
      42
  1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
  2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
  3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
  5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
  6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
  7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
  8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
  9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
  9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
 11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
 11  9    -1.00000 11 12     1.00000
      11
  1        1.00000  2        1.00000  3        1.00000  4        1.00000
  5        1.00000  6        1.00000  7        1.00000  8        0.00000
  9        0.00000 10        1.00000 11        0.00000
      48
  1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
  3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
  5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
  6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
  7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
  9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
 10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
 11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
 12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
 13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
 14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
      14
  1        1.0000   2        1.00000  3        1.00000  4        1.00000
  5        1.0000   6        1.00000  7        1.00000  8        1.00000
  9        1.0000  10        1.00000 11        1.00000 12        1.00000
 13        1.0000  14        1.00000
      36
  1  1   -37.5000   1  2   -39.90000  1  3   -47.70000  1  4   -37.80000
  1  5    -6.6000   1  6   -10.20000  1  7   -47.20000  1  8    -6.60000
  1  9    -7.8000   1 10   -50.00000  1 11   -10.20000  1 12    -7.80000
  2  1    -0.5900   2  2     0.00000  2  3    -0.41200  2  4    -0.65000
  2  5    -0.0000   2  6     0.00000  2  7     0.00000  2  8     0.00000
  2  9     0.0000   2 10    -0.41600  2 11     0.00000  2 12     0.00000
  3  1   -11.8700   3  2   -16.56000  3  3   -22.37000  3  4    -3.80000
  3  5    -4.9200   3  6    -7.60000  3  7   -15.71000  3  8    -4.92000
  3  9    -5.8100   3 10   -21.52000  3 11    -7.60000  3 12    -5.81000
```

```
NAME           SCENARIO 1 LAMBDA SET (0,1,0)
     850          3       12         2       11       14          0         40
       6
  1  1      1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7      1.00000  2 10      1.00000
      2
  1         1.00000  2         1.00000
      42
  1  1      1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
  2  5      1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
  3  9      1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
  5  4      1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
  6  8      1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
  7 12      1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.00000
  8  6     -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.00000
  9  6      1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
  9 12     -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
 11  2      1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
 11  9     -1.00000 11 12      1.00000
      11
  1         1.00000  2         1.00000  3         1.00000  4         1.00000
  5         1.00000  6         1.00000  7         1.00000  8         0.00000
  9         0.00000 10         1.00000 11         0.00000
      48
  1  1      1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7      1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
  3 11      1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
  5  3      1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
  6  5      1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00000
  7  9      1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00000
  9  2      1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
 10  7      1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
 11  1      1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
 12  4      1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
 13  4      1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
 14  1      1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
      14
  1         1.0000   2         1.00000  3         1.00000  4         1.00000
  5         1.0000   6         1.00000  7         1.00000  8         1.00000
  9         1.0000  10         1.00000 11         1.00000 12         1.00000
 13         1.0000  14         1.00000
      36
  1  1    -75.5000   1  2    -62.90000  1  3   -101.90000  1  4    -57.20000
  1  5    -10.2000   1  6    -57.60000  1  7    -61.70000  1  8    -10.20000
  1  9    -10.2000   1 10   -112.20000  1 11    -57.60000  1 12    -10.20000
  2  1     -0.0000   2  2      0.00000  2  3     -0.00000  2  4     -0.00000
  2  5     -0.0000   2  6     -0.00000  2  7     -0.00000  2  8      0.00000
  2  9      0.0000   2 10     -0.00000  2 11      0.00000  2 12      0.00000
  3  1    -31.2700   3  2    -26.18000  3  3    -27.930000 3  4    -16.07000
  3  5    -23.1700   3  6    -43.28000  3  7    -19.42000  3  8    -23.17000
  3  9    -23.1700   3 10     -4.50000  3 11    -43.28000  3 12    -23.17000
```

```
NAME          SCENARIO 1 LAMBDA SET (0,0,1)
     850        3       12         2        11       14          0        40
       6
  1  1     1.00000  1  2      1.00000  1  3     1.00000  2  4      1.00000
  2  7     1.00000  2 10      1.00000
     2
  1        1.00000  2         1.00000
      42
  1  1     1.00000  1  8      1.00000  1 11     1.00000  2  2      1.00000
  2  5     1.00000  2 12      1.00000  3  3     1.00000  3  6      1.00000
  3  9     1.00000  4  1      1.00000  4  2     1.00000  4  3      1.00000
  5  4     1.00000  5  5      1.00000  5  6     1.00000  6  7      1.00000
  6  8     1.00000  6  9      1.00000  7 10     1.00000  7 11      1.00000
  7 12     1.00000  8  1      1.00000  8  4    -1.00000  8  5     -1.00000
  8  6    -1.00000  8  8      1.00000  8 11     1.00000  9  3      1.00000
  9  6     1.00000  9  9      1.00000  9 10    -1.00000  9 11     -1.00000
  9 12    -1.00000 10  4      1.00000 10  7     1.00000 10 10      1.00000
 11  2     1.00000 11  5      1.00000 11  7    -1.00000 11  8     -1.00000
 11  9    -1.00000 11 12      1.00000
      11
  1        1.00000  2         1.00000  3        1.00000  4         1.00000
  5        1.00000  6         1.00000  7        1.00000  8         0.00000
  9        0.00000 10         1.00000 11        0.00000
      48
  1  1     1.0000   1  2      1.00000  1  3     1.00000  2  4      1.00000
  2  7     1.0000   2 10      1.00000  3  1     1.00000  3  8      1.00000
  3 11     1.0000   4  2      1.00000  4  5     1.00000  4 12      1.00000
  5  3     1.0000   5  6      1.00000  5  9     1.00000  6  4      1.00000
  6  5     1.0000   6  6      1.00000  7  7     1.00000  7  8      1.00000
  7  9     1.0000   8 10      1.00000  8 11     1.00000  8 12      1.00000
  9  2     1.0000   9  3      1.00000  9  5     1.00000  9  6      1.00000
 10  7     1.0000  10  8      1.00000 10 10     1.00000 10 11      1.00000
 11  1     1.0000  11  2      1.00000 11 11     1.00000 11 12      1.00000
 12  4     1.0000  12  6      1.00000 12  7     1.00000 12  9      1.00000
 13  4     1.0000  13  5      1.00000 13 10     1.00000 13 12      1.00000
 14  1     1.0000  14  3      1.00000 14  8     1.00000 14  9      1.00000
      14
  1        1.0000   2         1.00000  3        1.00000  4         1.00000
  5        1.0000   6         1.00000  7        1.00000  8         1.00000
  9        1.0000  10         1.00000 11        1.00000 12         1.00000
 13        1.0000  14         1.00000
      36
  1  1   -81.8000   1  2    -88.40000  1  3   -81.20000  1  4   -100.50000
  1  5    -6.6000   1  6    -37.40000  1  7   -92.10000  1  8     -6.60000
  1  9    -7.8000   1 10    -90.70000  1 11   -54.20000  1 12     -7.80000
  2  1    -1.4400   2  2     -1.20000  2  3    -0.70200  2  4     -0.80300
  2  5    -0.0000   2  6     -0.00000  2  7    -0.65000  2  8      0.00000
  2  9     0.0000   2 10     -0.65000  2 11     0.70500  2 12      0.00000
  3  1    -0.0000   3  2     -6.26000  3  3    -2.96000  3  4     -0.00000
  3  5    -4.9200   3  6     -2.46000  3  7    -6.26000  3  8     -4.92000
  3  9    -5.8100   3 10     -2.46000  3 11    -2.46000  3 12     -5.81000
```

```
NAME          SCENARIO 1 LAMBDA SET (.333,.333,.333)
     850        3      12        2        11      14          0        40
       6
 1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.00000  2 10     1.00000
       2
 1        1.00000  2        1.00000
      42
 1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
 2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
 3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
 5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
 6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
 7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
 8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
 9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
 9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
11  9    -1.00000 11 12     1.00000
      11
 1        1.00000  2        1.00000  3        1.00000  4        1.00000
 5        1.00000  6        1.00000  7        1.00000  8        0.00000
 9        0.00000 10        1.00000 11        0.00000
      48
 1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
 3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
 5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
 6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
 7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
 9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
      14
 1        1.0000   2        1.00000  3        1.00000  4        1.00000
 5        1.0000   6        1.00000  7        1.00000  8        1.00000
 9        1.0000  10        1.00000 11        1.00000 12        1.00000
13        1.0000  14        1.00000
      36
 1  1   -37.8000   1  2   -42.20000  1  3   -50.10000  1  4   -37.90000
 1  5    -6.6000   1  6   -10.20000  1  7   -42.30000  1  8    -6.60000
 1  9    -7.8000   1 10   -50.20000  1 11   -10.20000  1 12    -7.80000
 2  1    -0.6500   2  2    -0.41600  2  3    -0.82800  2  4    -0.59900
 2  5     0.0000   2  6     0.00000  2  7    -0.41600  2  8     0.00000
 2  9     0.0000   2 10    -0.77800  2 11     0.00000  2 12     0.00000
 3  1    -0.0000   3  2    -8.52000  3  3    -6.26000  3  4    -4.08000
 3  5    -4.9200   3  6    -7.60000  3  7    -8.56000  3  8    -4.92000
 3  9    -5.8100   3 10    -8.56000  3 11    -7.60000  3 12    -5.81000
```

```
NAME          SCENARIO 1 LAMBDA SET (.25,.375,.375)
    850         3        12         2        11        14          0         40
      6
 1  1      1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
 2  7      1.00000  2 10      1.00000
     2
 1         1.00000  2         1.00000
    42
 1  1      1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
 2  5      1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
 3  9      1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
 5  4      1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
 6  8      1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
 7 12      1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.00000
 8  6     -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.00000
 9  6      1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
 9 12     -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
11  2      1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
11  9     -1.00000 11 12      1.00000
    11
 1         1.00000  2         1.00000  3         1.00000  4         1.00000
 5         1.00000  6         1.00000  7         1.00000  8         0.00000
 9         0.00000 10         1.00000 11         0.00000
    48
 1  1      1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
 2  7      1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
 3 11      1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
 5  3      1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
 6  5      1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00000
 7  9      1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00000
 9  2      1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
10  7      1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
11  1      1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
12  4      1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
13  4      1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
14  1      1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
    14
 1         1.0000   2         1.00000  3         1.00000  4         1.00000
 5         1.0000   6         1.00000  7         1.00000  8         1.00000
 9         1.0000  10         1.00000 11         1.00000 12         1.00000
13         1.0000  14         1.00000
    36
 1  1    -37.8000   1  2    -44.40000  1  3    -50.10000  1  4    -37.90000
 1  5     -6.6000   1  6    -10.20000  1  7    -42.30000  1  8     -6.60000
 1  9     -7.8000   1 10    -54.80000  1 11    -10.20000  1 12     -7.80000
 2  1     -0.6500   2  2     -0.56700  2  3     -0.82800  2  4     -0.59900
 2  5     -0.0000   2  6     -0.00000  2  7     -0.41600  2  8      0.00000
 2  9      0.0000   2 10     -0.70500  2 11      0.00000  2 12      0.00000
 3  1     -0.0000   3  2     -6.26000  3  3     -6.26000  3  4     -4.08000
 3  5     -4.9200   3  6     -7.60000  3  7     -8.56000  3  8     -4.92000
 3  9     -5.8100   3 10     -4.92000  3 11     -7.60000  3 12     -5.81000
```

```
NAME          SCENARIO 1 LAMBDA SET (.375,.25,.375)
    850         3     12          2        11       14          0        40
      6
  1  1       1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7       1.00000  2 10      1.00000
      2
  1          1.00000  2         1.00000
     42
  1  1       1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
  2  5       1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
  3  9       1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
  5  4       1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
  6  8       1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
  7 12       1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.00000
  8  6      -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.00000
  9  6       1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
  9 12      -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
 11  2       1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
 11  9      -1.00000 11 12      1.00000
     11
  1          1.00000  2         1.00000  3         1.00000  4         1.00000
  5          1.00000  6         1.00000  7         1.00000  8         0.00000
  9          0.00000 10         1.00000 11         0.00000
     48
  1  1       1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7       1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
  3 11       1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
  5  3       1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
  6  5       1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00000
  7  9       1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00000
  9  2       1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
 10  7       1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
 11  1       1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
 12  4       1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
 13  4       1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
 14  1       1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
     14
  1          1.0000   2         1.00000  3         1.00000  4         1.00000
  5          1.0000   6         1.00000  7         1.00000  8         1.00000
  9          1.0000  10         1.00000 11         1.00000 12         1.00000
 13          1.0000  14         1.00000
     36
  1  1     -37.8000   1  2    -42.30000  1  3    -50.10000  1  4    -37.90000
  1  5      -6.6000   1  6    -10.20000  1  7    -42.30000  1  8     -6.60000
  1  9      -7.8000   1 10    -50.20000  1 11    -10.20000  1 12     -7.80000
  2  1      -0.0000   2  2     -0.41600  2  3     -0.82800  2  4     -0.59900
  2  5      -0.0000   2  6     -0.00000  2  7     -0.41600  2  8      0.00000
  2  9       0.0000   2 10     -0.77800  2 11      0.00000  2 12      0.00000
  3  1      -0.0000   3  2     -8.52000  3  3     -6.26000  3  4     -4.08000
  3  5      -4.9200   3  6     -7.60000  3  7     -8.56000  3  8     -4.92000
  3  9      -5.8100   3 10     -8.56000  3 11     -7.60000  3 12     -5.31000
```

```
NAME            SCENARIO 1 LAMBDA SET (.375,.375,.25)
     850          3       12         2        11      14          0        40
       6
  1  1       1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7       1.00000  2 10      1.00000
     2
  1          1.00000  2         1.00000
      42
  1  1       1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
  2  5       1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
  3  9       1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
  5  4       1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
  6  8       1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
  7 12       1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.00000
  8  6      -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.00000
  9  6       1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
  9 12      -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
 11  2       1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
 11  9      -1.00000 11 12      1.00000
      11
  1          1.00000  2         1.00000  3         1.00000  4         1.00000
  5          1.00000  6         1.00000  7         1.00000  8         0.00000
  9          0.00000 10         1.00000 11         0.00000
      48
  1  1       1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7       1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
  3 11       1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
  5  3       1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
  6  5       1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00000
  7  9       1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00000
  9  2       1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
 10  7       1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
 11  1       1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
 12  4       1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
 13  4       1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
 14  1       1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
      14
  1          1.0000   2         1.00000  3         1.00000  4         1.00000
  5          1.0000   6         1.00000  7         1.00000  8         1.00000
  9          1.0000  10         1.00000 11         1.00000 12         1.00000
 13          1.0000  14         1.00000
      36
  1  1     -37.8000   1  2    -40.30000  1  3    -50.10000  1  4    -37.90000
  1  5      -6.6000   1  6    -10.20000  1  7    -40.40000  1  8     -6.60000
  1  9      -7.8000   1 10    -48.20000  1 11    -10.20000  1 12     -7.80000
  2  1      -0.6500   2  2     -0.47600  2  3     -0.82800  2  4     -0.59900
  2  5      -0.0000   2  6     -0.00000  2  7     -0.47600  2  8      0.00000
  2  9       0.0000   2 10     -0.41600  2 11      0.00000  2 12      0.00000
  3  1      -0.0000   3  2    -10.72000  3  3     -6.26000  3  4     -4.08000
  3  5      -4.9200   3  6     -7.60000  3  7     -8.56000  3  8     -4.92000
  3  9      -5.8100   3 10    -11.39000  3 11     -7.60000  3 12     -5.81000
```

```
NAME          SCENARIO 1 LAMBDA SET (.5,.25,.25)
     850          3        12          2        11       14          0        40
       6
  1  1      1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7      1.00000  2 10     1.00000
     2
  1         1.00000  2        1.00000
     42
  1  1      1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
  2  5      1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
  3  9      1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
  5  4      1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
  6  8      1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
  7 12      1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
  8  6     -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
  9  6      1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
  9 12     -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
 11  2      1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
 11  9     -1.00000 11 12     1.00000
     11
  1         1.00000  2        1.00000  3        1.00000  4        1.00000
  5         1.00000  6        1.00000  7        1.00000  8        0.00000
  9         0.00000 10        1.00000 11        0.00000
     48
  1  1      1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7      1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
  3 11      1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
  5  3      1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
  6  5      1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
  7  9      1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
  9  2      1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
 10  7      1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
 11  1      1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
 12  4      1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
 13  4      1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
 14  1      1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
     14
  1         1.0000   2        1.00000  3        1.00000  4        1.00000
  5         1.0000   6        1.00000  7        1.00000  8        1.00000
  9         1.0000  10        1.00000 11        1.00000 12        1.00000
 13         1.0000  14        1.00000
     36
  1  1    -37.8000   1  2   -40.30000  1  3   -50.10000  1  4   -37.90000
  1  5     -6.6000   1  6   -10.20000  1  7   -40.40000  1  8    -6.60000
  1  9     -7.8000   1 10   -48.20000  1 11   -10.20000  1 12    -7.80000
  2  1     -0.6500   2  2    -0.47600  2  3    -0.82800  2  4    -0.59900
  2  5     -0.0000   2  6    -0.00000  2  7    -0.47600  2  8     0.00000
  2  9      0.0000   2 10    -0.41600  2 11     0.00000  2 12     0.00000
  3  1     -0.0000   3  2   -10.72000  3  3    -6.26000  3  4    -4.08000
  3  5     -4.9200   3  6    -7.60000  3  7    -8.56000  3  8    -4.92000
  3  9     -5.8100   3 10   -11.39000  3 11    -7.60000  3 12    -5.81000
```

```
NAME             SCENARIO 1 LAMBDA SET (.25,.5,.25)
     850          3       12         2         11         14          0          40
       6
  1  1       1.00000  1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7       1.00000  2 10       1.00000
     2
  1          1.00000  2          1.00000
     42
  1  1       1.00000  1  8       1.00000  1 11       1.00000  2  2       1.00000
  2  5       1.00000  2 12       1.00000  3  3       1.00000  3  6       1.00000
  3  9       1.00000  4  1       1.00000  4  2       1.00000  4  3       1.00000
  5  4       1.00000  5  5       1.00000  5  6       1.00000  6  7       1.00000
  6  8       1.00000  6  9       1.00000  7 10       1.00000  7 11       1.00000
  7 12       1.00000  8  1       1.00000  8  4      -1.00000  8  5      -1.00000
  8  6      -1.00000  8  8       1.00000  8 11       1.00000  9  3       1.00000
  9  6       1.00000  9  9       1.00000  9 10      -1.00000  9 11      -1.00000
  9 12      -1.00000 10  4       1.00000 10  7       1.00000 10 10       1.00000
 11  2       1.00000 11  5       1.00000 11  7      -1.00000 11  8      -1.00000
 11  9      -1.00000 11 12       1.00000
     11
  1          1.00000  2          1.00000  3          1.00000  4          1.00000
  5          1.00000  6          1.00000  7          1.00000  8          0.00000
  9          0.00000 10          1.00000 11          0.00000
     48
  1  1       1.0000   1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7       1.0000   2 10       1.00000  3  1       1.00000  3  8       1.00000
  3 11       1.0000   4  2       1.00000  4  5       1.00000  4 12       1.00000
  5  3       1.0000   5  6       1.00000  5  9       1.00000  6  4       1.00000
  6  5       1.0000   6  6       1.00000  7  7       1.00000  7  8       1.00000
  7  9       1.0000   8 10       1.00000  8 11       1.00000  8 12       1.00000
  9  2       1.0000   9  3       1.00000  9  5       1.00000  9  6       1.00000
 10  7       1.0000  10  8       1.00000 10 10       1.00000 10 11       1.00000
 11  1       1.0000  11  2       1.00000 11 11       1.00000 11 12       1.00000
 12  4       1.0000  12  6       1.00000 12  7       1.00000 12  9       1.00000
 13  4       1.0000  13  5       1.00000 13 10       1.00000 13 12       1.00000
 14  1       1.0000  14  3       1.00000 14  8       1.00000 14  9       1.00000
     14
  1          1.0000   2          1.00000  3          1.00000  4          1.00000
  5          1.0000   6          1.00000  7          1.00000  8          1.00000
  9          1.0000  10          1.00000 11          1.00000 12          1.00000
 13          1.0000  14          1.00000
     36
  1  1     -37.8000   1  2     -42.20000  1  3     -50.10000  1  4     -37.90000
  1  5      -6.6000   1  6     -10.20000  1  7     -42.30000  1  8      -6.60000
  1  9      -7.8000   1 10     -50.20000  1 11     -10.20000  1 12      -7.80000
  2  1      -0.6500   2  2      -0.41600  2  3      -0.82800  2  4      -0.59900
  2  5      -0.0000   2  6      -0.00000  2  7      -0.41600  2  8       0.00000
  2  9       0.0000   2 10      -0.77800  2 11       0.00000  2 12       0.00000
  3  1      -0.0000   3  2      -8.52000  3  3      -6.26000  3  4      -4.08000
  3  5      -4.9200   3  6      -7.60000  3  7      -8.56000  3  8      -4.92000
  3  9      -5.8100   3 10      -8.56000  3 11      -7.60000  3 12      -5.81000
```

```
NAME          SCENARIO 1 LAMBDA SET (.25,.25,.5)
   850           3       12          2       11       14          0        40
     6
 1  1      1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
 2  7      1.00000  2 10      1.00000
    2
 1         1.00000  2         1.00000
    42
 1  1      1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
 2  5      1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
 3  9      1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
 5  4      1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
 6  8      1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
 7 12      1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.[illegible]
 8  6     -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.[illegible]000
 9  6      1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
 9 12     -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
11  2      1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
11  9     -1.00000 11 12      1.00000
    11
 1         1.00000  2         1.00000  3         1.00000  4         1.00000
 5         1.00000  6         1.00000  7         1.00000  8         0.00000
 9         0.00000 10         1.00000 11         0.00000
    48
 1  1      1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
 2  7      1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
 3 11      1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
 5  3      1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
 6  5      1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00000
 7  9      1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00000
 9  2      1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
10  7      1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
11  1      1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
12  4      1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
13  4      1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
14  1      1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
    14
 1         1.0000   2         1.00000  3         1.00000  4         1.00000
 5         1.0000   6         1.00000  7         1.00000  8         1.00000
 9         1.0000  10         1.00000 11         1.00000 12         1.00000
13         1.0000  14         1.00000
    36
 1  1    -37.8000   1  2    -44.40000  1  3    -52.20000  1  4    -44.60000
 1  5     -6.6000   1  6    -10.20000  1  7    -42.30000  1  8     -6.60000
 1  9     -7.8000   1 10    -54.80000  1 11    -10.20000  1 12     -7.80000
 2  1     -0.6500   2  2     -0.56700  2  3     -0.77300  2  4     -0.83300
 2  5     -0.0000   2  6     -0.00000  2  7     -0.41600  2  8      0.00000
 2  9      0.0000   2 10     -0.70400  2 11      0.00000  2 12      0.00000
 3  1     -0.0000   3  2     -6.26000  3  3     -4.92000  3  4     -0.00000
 3  5     -4.9200   3  6     -7.60000  3  7     -8.56000  3  8     -4.92000
 3  9     -5.8100   3 10     -4.92000  3 11     -7.60000  3 12     -5.81000
```

```
NAME          SCENARIO 2 LAMBDA SET (1,0,0)
     850        3       12        2        11       14        0        40
       6
  1  1      1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7      1.00000  2 10     1.00000
       2
  1         1.00000  2        1.00000
      42
  1  1      1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
  2  5      1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
  3  9      1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
  5  4      1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
  6  8      1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
  7 12      1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
  8  6     -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
  9  6      1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
  9 12     -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
 11  2      1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
 11  9     -1.00000 11 12     1.00000
      11
  1         1.00000  2        1.00000  3        1.00000  4        1.00000
  5         1.00000  6        1.00000  7        1.00000  8        0.00000
  9         0.00000 10        1.00000 11        0.00000
      48
  1  1      1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7      1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
  3 11      1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
  5  3      1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
  6  5      1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
  7  9      1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
  9  2      1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
 10  7      1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
 11  1      1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
 12  4      1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
 13  4      1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
 14  1      1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
      14
  1         1.0000   2        1.00000  3        1.00000  4        1.00000
  5         1.0000   6        1.00000  7        1.00000  8        1.00000
  9         1.0000  10        1.00000 11        1.00000 12        1.00000
 13         1.0000  14        1.00000
      36
  1  1    -37.5000   1  2   -39.90000  1  3   -47.70000  1  4   -37.80000
  1  5     -6.6000   1  6   -10.20000  1  7   -42.20000  1  8    -6.60000
  1  9     -7.8000   1 10   -30.00000  1 11   -10.20000  1 12    -7.80000
  2  1     -0.5900   2  2    -0.23300  2  3    -2.19000  2  4    -0.65000
  2  5     -0.3020   2  6    -1.60000  2  7    -0.23300  2  8    -0.30200
  2  9     -2.0900   2 10    -2.59000  2 11    -1.60000  2 12    -2.09000
  3  1    -11.8700   3  2   -16.56000  3  3   -22.37000  3  4    -3.80000
  3  5     -4.9200   3  6    -7.60000  3  7   -15.71000  3  8    -4.92000
  3  9     -5.8100   3 10   -21.52000  3 11    -7.60000  3 12    -5.81000
```

```
NAME          SCENARIO 2 LAMBDA SET (0,1,0)
    850        3       12        2        11       14        0        40
      6
 1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.00000  2 10     1.00000
     2
 1        1.00000  2        1.00000
     42
 1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
 2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
 3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
 5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
 6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
 7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
 8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
 9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
 9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
11  9    -1.00000 11 12     1.00000
     11
 1        1.00000  2        1.00000  3        1.00000  4        1.00000
 5        1.00000  6        1.00000  7        1.00000  8        0.00000
 9        0.00000 10        1.00000 11        0.00000
     48
 1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
 3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
 5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
 6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
 7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
 9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
     14
 1        1.0000   2        1.00000  3        1.00000  4        1.00000
 5        1.0000   6        1.00000  7        1.00000  8        1.00000
 9        1.0000  10        1.00000 11        1.00000 12        1.00000
13        1.0000  14        1.00000
     36
 1  1   -70.7000   1  2   -61.20000  1  3   -75.20000  1  4   -59.10000
 1  5   -20.4000   1  6   -10.30000  1  7   -63.60000  1  8   -20.40000
 1  9   -10.3000   1 10   -61.40000  1 11   -10.30000  1 12   -10.30000
 2  1    -0.0000   2  2    -0.00000  2  3    -0.96600  2  4    -0.00000
 2  5    -0.0000   2  6    -0.96600  2  7    -0.00000  2  8    -0.00000
 2  9    -0.9660   2 10    -1.10000  2 11    -0.97500  2 12    -0.97500
 3  1    -3.8000   3  2   -34.30000  3  3   -42.02000  3  4   -28.81000
 3  5   -15.7700   3  6    -7.67000  3  7   -34.33000  3  8   -15.20000
 3  9    -7.6700   3 10   -32.69000  3 11    -7.67000  3 12    -7.67000
```

```
NAME           SCENARIO 2 LAMBDA SET (0,0,1)
    850       3      12        2       11       14          0       40
      6
 1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.00000  2 10     1.00000
     2
 1        1.00000  2        1.00000
     42
 1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
 2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
 3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
 5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
 6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
 7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
 8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
 9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
 9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
11  9    -1.00000 11 12     1.00000
     11
 1        1.00000  2        1.00000  3        1.00000  4        1.00000
 5        1.00000  6        1.00000  7        1.00000  8        0.00000
 9        0.00000 10        1.00000 11        0.00000
     48
 1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
 3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
 5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
 6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
 7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
 9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
     14
 1        1.0000   2        1.00000  3        1.00000  4        1.00000
 5        1.0000   6        1.00000  7        1.00000  8        1.00000
 9        1.0000  10        1.00000 11        1.00000 12        1.00000
13        1.0000  14        1.00000
     36
 1  1   -81.8000   1  2   -88.40000  1  3   -81.20000  1  4  -100.50000
 1  5    -6.6000   1  6   -37.40000  1  7   -92.10000  1  8    -6.60000
 1  9    -7.8000   1 10   -90.70000  1 11   -54.20000  1 12    -7.80000
 2  1   -10.1400   2  2   -10.44000  2  3   -21.700000  2  4    -3.90000
 2  5    -0.3020   2  6    -2.00000  2  7    -4.47000  2  8    -0.30200
 2  9    -2.0900   2 10    -2.15000  2 11    -3.18000  2 12    -2.09000
 3  1    -0.0000   3  2    -4.29000  3  3    -2.98000  3  4    -0.00000
 3  5    -4.9200   3  6    -2.46000  3  7    -6.26000  3  8    -4.92000
 3  9    -5.8100   3 10    -2.46000  3 11    -2.46000  3 12    -5.81000
```

```
NAME            SCENARIO 2 LAMBDA SET (.333,.333,.333)
     850         3        12          2        11       14          0         40
       6
  1  1       1.00000  1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7       1.00000  2 10       1.00000
       2
  1          1.00000  2          1.00000
      42
  1  1       1.00000  1  8       1.00000  1 11       1.00000  2  2       1.00000
  2  5       1.00000  2 12       1.00000  3  3       1.00000  3  6       1.00000
  3  9       1.00000  4  1       1.00000  4  2       1.00000  4  3       1.00000
  5  4       1.00000  5  5       1.00000  5  6       1.00000  6  7       1.00000
  6  8       1.00000  6  9       1.00000  7 10       1.00000  7 11       1.00000
  7 12       1.00000  8  1       1.00000  8  4      -1.00000  8  5      -1.00000
  8  6      -1.00000  8  8       1.00000  8 11       1.00000  9  3       1.00000
  9  6       1.00000  9  9       1.00000  9 10      -1.00000  9 11      -1.00000
  9 12      -1.00000 10  4       1.00000 10  7       1.00000 10 10       1.00000
 11  2       1.00000 11  5       1.00000 11  7      -1.00000 11  8      -1.00000
 11  9      -1.00000 11 12       1.00000
      11
  1          1.00000  2          1.00000  3          1.00000  4          1.00000
  5          1.00000  6          1.00000  7          1.00000  8          0.00000
  9          0.00000 10          1.00000 11          0.00000
      48
  1  1       1.0000   1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7       1.0000   2 10       1.00000  3  1       1.00000  3  8       1.00000
  3 11       1.0000   4  2       1.00000  4  5       1.00000  4 12       1.00000
  5  3       1.0000   5  6       1.00000  5  9       1.00000  6  4       1.00000
  6  5       1.0000   6  6       1.00000  7  7       1.00000  7  8       1.00000
  7  9       1.0000   8 10       1.00000  8 11       1.00000  8 12       1.00000
  9  2       1.0000   9  3       1.00000  9  5       1.00000  9  6       1.00000
 10  7       1.0000  10  8       1.00000 10 10       1.00000 10 11       1.00000
 11  1       1.0000  11  2       1.00000 11 11       1.00000 11 12       1.00000
 12  4       1.0000  12  6       1.00000 12  7       1.00000 12  9       1.00000
 13  4       1.0000  13  5       1.00000 13 10       1.00000 13 12       1.00000
 14  1       1.0000  14  3       1.00000 14  8       1.00000 14  9       1.00000
      14
  1          1.0000   2          1.00000  3          1.00000  4          1.00000
  5          1.0000   6          1.00000  7          1.00000  8          1.00000
  9          1.0000  10          1.00000 11          1.00000 12          1.00000
 13          1.0000  14          1.00000
      36
  1  1     -37.8000   1  2     -42.20000  1  3     -50.20000  1  4     -40.30000
  1  5      -6.6000   1  6     -10.30000  1  7     -42.30000  1  8      -6.60000
  1  9      -7.8000   1 10     -50.60000  1 11     -10.30000  1 12      -7.80000
  2  1      -0.6500   2  2      -0.65000  2  3      -1.71000  2  4      -0.80500
  2  5      -0.3020   2  6      -0.96600  2  7      -0.65000  2  8      -0.30200
  2  9      -2.0900   2 10      -1.67000  2 11      -0.97500  2 12      -2.09000
  3  1      -0.0000   3  2      -9.52000  3  3      -6.33000  3  4      -0.00000
  3  5      -4.9200   3  6      -7.67000  3  7      -8.56000  3  8      -4.92000
  3  9      -5.8100   3 10      -8.46000  3 11      -7.67000  3 12      -5.81000
```

```
NAME           SCENARIO 2 LAMBDA SET (.25,.375,.375)
     850          3         12          2         11        14          0         40
       6
  1   1      1.00000   1   2      1.00000   1   3      1.00000   2   4      1.00000
  2   7      1.00000   2  10      1.00000
     2
  1          1.00000   2          1.00000
      42
  1   1      1.00000   1   8      1.00000   1  11      1.00000   2   2      1.00000
  2   5      1.00000   2  12      1.00000   3   3      1.00000   3   6      1.00000
  3   9      1.00000   4   1      1.00000   4   2      1.00000   4   3      1.00000
  5   4      1.00000   5   5      1.00000   5   6      1.00000   6   7      1.00000
  6   8      1.00000   6   9      1.00000   7  10      1.00000   7  11      1.00000
  7  12      1.00000   8   1      1.00000   8   4     -1.00000   8   5     -1.00000
  8   6     -1.00000   8   8      1.00000   8  11      1.00000   9   3      1.00000
  9   6      1.00000   9   9      1.00000   9  10     -1.00000   9  11     -1.00000
  9  12     -1.00000  10   4      1.00000  10   7      1.00000  10  10      1.00000
 11   2      1.00000  11   5      1.00000  11   7     -1.00000  11   8     -1.00000
 11   9     -1.00000  11  12      1.00000
      11
  1          1.00000   2          1.00000   3          1.00000   4          1.00000
  5          1.00000   6          1.00000   7          1.00000   8          0.00000
  9          0.00000  10          1.00000  11          0.00000
      48
  1   1      1.0000    1   2      1.00000   1   3      1.00000   2   4      1.00000
  2   7      1.0000    2  10      1.00000   3   1      1.00000   3   8      1.00000
  3  11      1.0000    4   2      1.00000   4   5      1.00000   4  12      1.00000
  5   3      1.0000    5   6      1.00000   5   9      1.00000   6   4      1.00000
  6   5      1.0000    6   6      1.00000   7   7      1.00000   7   8      1.00000
  7   9      1.0000    8  10      1.00000   8  11      1.00000   8  12      1.00000
  9   2      1.0000    9   3      1.00000   9   5      1.00000   9   6      1.00000
 10   7      1.0000   10   8      1.00000  10  10      1.00000  10  11      1.00000
 11   1      1.0000   11   2      1.00000  11  11      1.00000  11  12      1.00000
 12   4      1.0000   12   6      1.00000  12   7      1.00000  12   9      1.00000
 13   4      1.0000   13   5      1.00000  13  10      1.00000  13  12      1.00000
 14   1      1.0000   14   3      1.00000  14   8      1.00000  14   9      1.00000
      14
  1          1.0000    2          1.00000   3          1.00000   4          1.00000
  5          1.0000    6          1.00000   7          1.00000   8          1.00000
  9          1.0000   10          1.00000  11          1.00000  12          1.00000
 13          1.0000   14          1.00000
      36
  1   1    -37.8000    1   2    -44.40000   1   3    -50.20000   1   4    -40.30000
  1   5     -6.6000    1   6    -10.30000   1   7    -42.30000   1   8     -6.60000
  1   9     -7.8000    1  10    -52.70000   1  11    -10.30000   1  12     -7.80000
  2   1     -0.6500    2   2     -0.80100   2   3     -1.71000   2   4     -0.70900
  2   5     -0.3020    2   6     -0.96600   2   7     -0.65000   2   8     -0.30200
  2   9     -2.0900    2  10     -1.78000   2  11     -0.97500   2  12     -2.09000
  3   1     -0.0000    3   2     -6.26000   3   3     -6.33000   3   4     -0.00000
  3   5     -4.9200    3   6     -7.67000   3   7     -8.56000   3   8     -4.92000
  3   9     -5.8100    3  10     -6.33000   3  11     -7.67000   3  12     -5.81000
```

```
NAME          SCENARIO 2 LAMBDA SET (.375,.25,.375)
     850       3      12        2      11      14        0      40
       6
  1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.00000  2 10     1.00000
       2
  1        1.00000  2        1.00000
      42
  1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
  2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
  3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
  5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
  6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
  7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
  8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
  9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
  9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
 11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
 11  9    -1.00000 11 12     1.00000
      11
  1        1.00000  2        1.00000  3        1.00000  4        1.00000
  5        1.00000  6        1.00000  7        1.00000  8        0.00000
  9        0.00000 10        1.00000 11        0.00000
      48
  1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
  3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
  5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
  6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
  7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
  9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
 10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
 11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
 12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
 13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
 14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
      14
  1        1.0000   2        1.00000  3        1.00000  4        1.00000
  5        1.0000   6        1.00000  7        1.00000  8        1.00000
  9        1.0000  10        1.00000 11        1.00000 12        1.00000
 13        1.0000  14        1.00000
      36
  1  1   -37.8000   1  2   -42.20000  1  3   -50.20000  1  4   -40.30000
  1  5    -6.6000   1  6   -10.30000  1  7   -42.30000  1  8    -6.60000
  1  9    -7.8000   1 10   -50.30000  1 11   -10.30000  1 12    -7.80000
  2  1    -0.6500   2  2    -0.65000  2  3    -1.77000  2  4    -0.70900
  2  5    -0.3020   2  6    -0.96600  2  7    -0.65000  2  8    -0.30200
  2  9    -2.0900   2 10    -1.67000  2 11    -0.97500  2 12    -2.09000
  3  1    -0.0000   3  2    -8.51000  3  3    -6.33000  3  4    -0.00000
  3  5    -4.9200   3  6    -7.67000  3  7    -8.56000  3  8    -4.92000
  3  9    -5.8100   3 10    -8.64000  3 11    -7.67000  3 12    -5.88000
```

```
NAME          SCENARIO 2 LAMBDA SET (.375,.375,.25)
     850         3       12        2       11     14          0       40
       6
  1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.00000  2 10     1.00000
     2
  1        1.00000  2        1.00000
      42
  1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
  2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
  3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
  5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
  6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
  7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
  8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
  9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
  9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
 11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
 11  9    -1.00000 11 12     1.00000
     11
  1        1.00000  2        1.00000  3        1.00000  4        1.00000
  5        1.00000  6        1.00000  7        1.00000  8        0.00000
  9        0.00000 10        1.00000 11        0.00000
     48
  1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
  3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
  5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
  6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
  7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
  9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
 10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
 11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
 12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
 13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
 14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
     14
  1        1.0000   2        1.00000  3        1.00000  4        1.00000
  5        1.0000   6        1.00000  7        1.00000  8        1.00000
  9        1.0000  10        1.00000 11        1.00000 12        1.00000
 13        1.0000  14        1.00000
     36
  1  1   -37.8000   1  2   -40.30000  1  3   -50.20000  1  4   -37.90000
  1  5    -6.6000   1  6   -10.30000  1  7   -40.40000  1  8    -6.60000
  1  9    -7.8000   1 10   -48.20000  1 11   -10.30000  1 12    -7.80000
  2  1    -0.6500   2  2    -0.70900  2  3    -1.71000  2  4    -0.70900
  2  5    -0.3020   2  6    -0.96600  2  7    -0.71400  2  8    -0.30200
  2  9    -2.0900   2 10    -1.57000  2 11    -0.97500  2 12    -2.09000
  3  1    -0.0000   3  2   -10.72000  3  3    -6.33000  3  4    -0.00000
  3  5    -4.9200   3  6    -7.67000  3  7   -10.79000  3  8    -4.92000
  3  9    -5.8100   3 10   -11.75000  3 11    -7.67000  3 12    -5.81000
```

```
NAME            SCENARIO 2 LAMBDA SET (.5,.25,.25)
     850          3         12          2         11         14          0          40
       6
  1  1        1.00000  1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7        1.00000  2 10       1.00000
      2
  1           1.00000  2          1.00000
      42
  1  1        1.00000  1  8       1.00000  1 11       1.00000  2  2       1.00000
  2  5        1.00000  2 12       1.00000  3  3       1.00000  3  6       1.00000
  3  9        1.00000  4  1       1.00000  4  2       1.00000  4  3       1.00000
  5  4        1.00000  5  5       1.00000  5  6       1.00000  6  7       1.00000
  6  8        1.00000  6  9       1.00000  7 10       1.00000  7 11       1.00000
  7 12        1.00000  8  1       1.00000  8  4      -1.00000  8  5      -1.00000
  8  6       -1.00000  8  8       1.00000  8 11       1.00000  9  3       1.00000
  9  6        1.00000  9  9       1.00000  9 10      -1.00000  9 11      -1.00000
  9 12       -1.00000 10  4       1.00000 10  7       1.00000 10 10       1.00000
 11  2        1.00000 11  5       1.00000 11  7      -1.00000 11  8      -1.00000
 11  9       -1.00000 11 12       1.00000
      11
  1           1.00000  2          1.00000  3          1.00000  4          1.00000
  5           1.00000  6          1.00000  7          1.00000  8          0.00000
  9           0.00000 10          1.00000 11          0.00000
      48
  1  1        1.0000   1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7        1.0000   2 10       1.00000  3  1       1.00000  3  8       1.00000
  3 11        1.0000   4  2       1.00000  4  5       1.00000  4 12       1.00000
  5  3        1.0000   5  6       1.00000  5  9       1.00000  6  4       1.00000
  6  5        1.0000   6  6       1.00000  7  7       1.00000  7  6       1.00000
  7  9        1.0000   8 10       1.00000  8 11       1.00000  8 12       1.00000
  9  2        1.0000   9  3       1.00000  9  5       1.00000  9  6       1.00000
 10  7        1.0000  10  8       1.00000 10 10       1.00000 10 11       1.00000
 11  1        1.0000  11  2       1.00000 11 11       1.00000 11 12       1.00000
 12  4        1.0000  12  6       1.00000 12  7       1.00000 12  9       1.00000
 13  4        1.0000  13  5       1.00000 13 10       1.00000 13 12       1.00000
 14  1        1.0000  14  3       1.00000 14  8       1.00000 14  9       1.00000
      14
  1           1.0000   2          1.00000  3          1.00000  4          1.00000
  5           1.0000   6          1.00000  7          1.00000  8          1.00000
  9           1.0000  10          1.00000 11          1.00000 12          1.00000
 13           1.0000  14          1.00000
      36
  1  1     -37.8000    1  2     -40.30000  1  3     -50.20000  1  4     -37.90000
  1  5      -6.6000    1  6     -10.30000  1  7     -40.40000  1  8      -6.60000
  1  9      -7.8000    1 10     -48.20000  1 11     -10.30000  1 12      -7.80000
  2  1      -0.6500    2  2      -0.70900  2  3      -1.71000  2  4      -0.70900
  2  5      -0.3020    2  6      -0.96600  2  7      -0.71400  2  8      -0.30200
  2  9      -2.0900    2 10      -1.57000  2 11      -0.97500  2 12      -2.09000
  3  1      -0.0000    3  2     -10.72000  3  3      -6.33000  3  4      -0.00000
  3  5      -4.9200    3  6      -7.67000  3  7     -10.79000  3  8      -4.92000
  3  9      -5.8100    3 10     -11.75000  3 11      -7.67000  3 12      -5.81000
```

```
NAME          SCENARIO 2 LAMBDA SET (.25,.5,.25)
     850        3       12        2       11       14         0       40
      6
 1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.00000  2 10     1.00000
     2
 1        1.00000  2        1.00000
    42
 1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
 2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
 3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
 5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
 6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
 7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
 8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
 9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
 9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
11  9    -1.00000 11 12     1.00000
    11
 1        1.00000  2        1.00000  3        1.00000  4        1.00000
 5        1.00000  6        1.00000  7        1.00000  8        0.00000
 9        0.00000 10        1.00000 11        0.00000
    48
 1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
 2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
 3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
 5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
 6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
 7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
 9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
    14
 1        1.0000   2        1.00000  3        1.00000  4        1.00000
 5        1.0000   6        1.00000  7        1.00000  8        1.00000
 9        1.0000  10        1.00000 11        1.00000 12        1.00000
13        1.0000  14        1.00000
    36
 1  1   -37.8000   1  2   -40.30000  1  3   -50.20000  1  4   -37.90000
 1  5    -6.6000   1  6   -10.30000  1  7   -40.40000  1  8    -6.60000
 1  9    -7.8000   1 10   -48.20000  1 11   -10.30000  1 12    -7.80000
 2  1    -0.6500   2  2    -0.70900  2  3    -1.71000  2  4    -0.70900
 2  5    -0.3020   2  6    -0.96600  2  7    -0.71400  2  8    -0.30200
 2  9    -2.0900   2 10    -1.57000  2 11    -0.97500  2 12    -2.09000
 3  1    -0.0000   3  2   -10.72000  3  3    -6.33000  3  4    -0.00000
 3  5    -4.9200   3  6    -7.67000  3  7   -10.79000  3  8    -4.92000
 3  9    -5.8100   3 10   -11.75000  3 11    -7.67000  3 12    -5.81000
```

```
NAME          SCENARIO 2 LAMBDA SET (.25,.25,.5)
   850        3       12        2       11      14          0        40
     6
 1  1       1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
 2  7       1.00000  2 10      1.00000
     2
 1          1.00000  2         1.00000
    42
 1  1       1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
 2  5       1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
 3  9       1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
 5  4       1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
 6  8       1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
 7 12       1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.00000
 8  6      -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.00000
 9  6       1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
 9 12      -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
11  2       1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
11  9      -1.00000 11 12      1.00000
    11
 1          1.00000  2         1.00000  3         1.00000  4         1.00000
 5          1.00000  6         1.00000  7         1.00000  8         0.00000
 9          0.00000 10         1.00000 11         0.00000
    48
 1  1       1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
 2  7       1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
 3 11       1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
 5  3       1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
 6  5       1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00[illegible]
 7  9       1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00[illegible]
 9  2       1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
10  7       1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
11  1       1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
12  4       1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
13  4       1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
14  1       1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
    14
 1          1.0000   2         1.00000  3         1.00000  4         1.00000
 5          1.0000   6         1.00000  7         1.00000  8         1.00000
 9          1.0000  10         1.00000 11         1.00000 12         1.00000
13          1.0000  14         1.00000
    36
 1  1     -37.8000   1  2    -42.20000  1  3    -50.20000  1  4    -40.30000
 1  5      -6.6000   1  6    -10.30000  1  7    -42.30000  1  8     -6.60000
 1  9      -7.8000   1 10    -50.30000  1 11    -10.30000  1 12     -7.80000
 2  1      -0.6500   2  2     -0.65000  2  3     -1.77000  2  4     -0.70900
 2  5      -0.3020   2  6     -0.96600  2  7     -0.65000  2  8     -0.30200
 2  9      -2.0900   2 10     -1.67000  2 11     -0.97500  2 12     -2.09000
 3  1      -0.0000   3  2     -8.51000  3  3     -6.33000  3  4     -0.00000
 3  5      -4.9200   3  6     -7.67000  3  7     -8.56000  3  8     -4.92000
 3  9      -5.8100   3 10     -8.64000  3 11     -7.67000  3 12     -5.88000
```

```
NAME           SCENARIO 3 IAMBDA SET (1,0,0)
     850          3       12        2       11       14          0        40
       6
  1  1       1.00000  1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7       1.00000  2 10       1.00000
      2
  1          1.00000  2          1.00000
      42
  1  1       1.00000  1  8       1.00000  1 11       1.00000  2  2       1.00000
  2  5       1.00000  2 12       1.00000  3  3       1.00000  3  6       1.00000
  3  9       1.00000  4  1       1.00000  4  2       1.00000  4  3       1.00000
  5  4       1.00000  5  5       1.00000  5  6       1.00000  6  7       1.00000
  6  8       1.00000  6  9       1.00000  7 10       1.00000  7 11       1.00000
  7 12       1.00000  8  1       1.00000  8  4      -1.00000  8  5      -1.00000
  8  6      -1.00000  8  8       1.00000  8 11       1.00000  9  3       1.00000
  9  6       1.00000  9  9       1.00000  9 10      -1.00000  9 11      -1.00000
  9 12      -1.00000 10  4       1.00000 10  7       1.00000 10 10       1.00000
 11  2       1.00000 11  5       1.00000 11  7      -1.00000 11  8      -1.00000
 11  9      -1.00000 11 12       1.00000
      11
  1          1.00000  2          1.00000  3          1.00000  4          1.00000
  5          1.00000  6          1.00000  7          1.00000  8          0.00000
  9          0.00000 10          1.00000 11          0.00000
      48
  1  1       1.0000   1  2       1.00000  1  3       1.00000  2  4       1.00000
  2  7       1.0000   2 10       1.00000  3  1       1.00000  3  8       1.00000
  3 11       1.0000   4  2       1.00000  4  5       1.00000  4 12       1.00000
  5  3       1.0000   5  6       1.00000  5  9       1.00000  6  4       1.00000
  6  5       1.0000   6  6       1.00000  7  7       1.00000  7  8       1.00000
  7  9       1.0000   8 10       1.00000  8 11       1.00000  8 12       1.00000
  9  2       1.0000   9  3       1.00000  9  5       1.00000  9  6       1.00000
 10  7       1.0000  10  8       1.00000 10 10       1.00000 10 11       1.00000
 11  1       1.0000  11  2       1.00000 11 11       1.00000 11 12       1.00000
 12  4       1.0000  12  6       1.00000 12  7       1.00000 12  9       1.00000
 13  4       1.0000  13  5       1.00000 13 10       1.00000 13 12       1.00000
 14  1       1.0000  14  3       1.00000 14  8       1.00000 14  9       1.00000
      14
  1          1.0000   2          1.00000  3          1.00000  4          1.00000
  5          1.0000   6          1.00000  7          1.00000  8          1.00000
  9          1.0000  10          1.00000 11          1.00000 12          1.00000
 13          1.0000  14          1.00000
      36
  1  1     -37.5000   1  2     -39.90000  1  3     -47.70000  1  4     -37.80000
  1  5      -6.6000   1  6     -10.20000  1  7     -42.20000  1  8      -6.60000
  1  9      -7.8000   1 10     -50.00000  1 11     -10.20000  1 12      -7.80000
  2  1      -3.0000   2  2      -2.72000  2  3      -7.16000  2  4      -3.45000
  2  5      -2.9300   2  6      -4.53000  2  7      -5.02000  2  8      -2.93000
  2  9      -4.6300   2 10      -9.66000  2 11      -4.53000  2 12      -4.63000
  3  1     -11.8700   3  2     -16.56000  3  3     -22.37000  3  4      -5.21000
  3  5      -4.9200   3  6      -7.60000  3  7     -15.71000  3  8      -4.92000
  3  9      -5.8100   3 10     -21.52000  3 11      -7.60000  3 12      -5.81000
```

```
NAME            SCENARIO 3 LAMBDA SET (0,1,0)
    850          3       12         2        11       14          0        40
      6
  1   1     1.00000  1   2     1.00000  1   3     1.00000  2   4     1.00000
  2   7     1.00000  2  10     1.00000
     2
  1         1.00000  2         1.00000
     42
  1   1     1.00000  1   8     1.00000  1  11     1.00000  2   2     1.00000
  2   5     1.00000  2  12     1.00000  3   3     1.00000  3   6     1.00000
  3   9     1.00000  4   1     1.00000  4   2     1.00000  4   3     1.00000
  5   4     1.00000  5   5     1.00000  5   6     1.00000  6   7     1.00000
  6   8     1.00000  6   9     1.00000  7  10     1.00000  7  11     1.00000
  7  12     1.00000  8   1     1.00000  8   4    -1.00000  8   5    -1.00000
  8   6    -1.00000  8   8     1.00000  8  11     1.00000  9   3     1.00000
  9   6     1.00000  9   9     1.00000  9  10    -1.00000  9  11    -1.00000
  9  12    -1.00000 10   4     1.00000 10   7     1.00000 10  10     1.00000
 11   2     1.00000 11   5     1.00000 11   7    -1.00000 11   8    -1.00000
 11   9    -1.00000 11  12     1.00000
     11
  1         1.00000  2         1.00000  3         1.00000  4         1.00000
  5         1.00000  6         1.00000  7         1.00000  8         0.00000
  9         0.00000 10         1.00000 11         0.00000
     48
  1   1     1.0000   1   2     1.00000  1   3     1.00000  2   4     1.00000
  2   7     1.0000   2  10     1.00000  3   1     1.00000  3   8     1.00000
  3  11     1.0000   4   2     1.00000  4   5     1.00000  4  12     1.00000
  5   3     1.0000   5   6     1.00000  5   9     1.00000  6   4     1.00000
  6   5     1.0000   6   6     1.00000  7   7     1.00000  7   8     1.00000
  7   9     1.0000   8  10     1.00000  8  11     1.00000  8  12     1.00000
  9   2     1.0000   9   3     1.00000  9   5     1.00000  9   6     1.00000
 10   7     1.0000  10   8     1.00000 10  10     1.00000 10  11     1.00000
 11   1     1.0000  11   2     1.00000 11  11     1.00000 11  12     1.00000
 12   4     1.0000  12   6     1.00000 12   7     1.00000 12   9     1.00000
 13   4     1.0000  13   5     1.00000 13  10     1.00000 13  12     1.00000
 14   1     1.0000  14   3     1.00000 14   8     1.00000 14   9     1.00000
     14
  1         1.0000   2         1.00000  3         1.00000  4         1.00000
  5         1.0000   6         1.00000  7         1.00000  8         1.00000
  9         1.0000  10         1.00000 11         1.00000 12         1.00000
 13         1.0000  14         1.00000
     36
  1   1   -54.7000   1   2   -39.90000  1   3   -65.10000  1   4   -79.70000
  1   5   -10.3000   1   6   -10.30000  1   7   -77.90000  1   8   -10.30000
  1   9   -10.3000   1  10   -67.20000  1  11   -10.30000  1  12   -10.30000
  2   1    -2.0900   2   2    -2.72000  2   3    -4.82000  2   4    -2.87000
  2   5    -2.7600   2   6    -3.65000  2   7    -3.40000  2   8    -2.76000
  2   9    -3.6500   2  10    -5.87000  2  11    -3.67000  2  12    -3.67000
  3   1   -14.2700   3   2   -16.56000  3   3   -21.32000  3   4   -41.20000
  3   5    -7.6700   3   6    -7.60000  3   7   -34.55000  3   8    -7.67000
  3   9    -7.6700   3  10    -6.50000  3  11    -7.60000  3  12    -5.81000
```

```
NAME            SCENARIO 3 LAMBDA SET (0,0,1)
     850        3      12        2      11      14        0       40
       6
 1  1     1.00000  1  2    1.00000  1  3    1.00000  2  4    1.00000
 2  7     1.00000  2 10    1.00000
      2
 1        1.00000  2       1.00000
      42
 1  1     1.00000  1  8    1.00000  1 11    1.00000  2  2    1.00000
 2  5     1.00000  2 12    1.00000  3  3    1.00000  3  6    1.00000
 3  9     1.00000  4  1    1.00000  4  2    1.00000  4  3    1.00000
 5  4     1.00000  5  5    1.00000  5  6    1.00000  6  7    1.00000
 6  8     1.00000  6  9    1.00000  7 10    1.00000  7 11    1.00000
 7 12     1.00000  8  1    1.00000  8  4   -1.00000  8  5   -1.00000
 8  6    -1.00000  8  8    1.00000  8 11    1.00000  9  3    1.00000
 9  6     1.00000  9  9    1.00000  9 10   -1.00000  9 11   -1.00000
 9 12    -1.00000 10  4    1.00000 10  7    1.00000 10 10    1.00000
11  2     1.00000 11  5    1.00000 11  7   -1.00000 11  8   -1.00000
11  9    -1.00000 11 12    1.00000
      11
 1        1.00000  2       1.00000  3       1.00000  4       1.00000
 5        1.00000  6       1.00000  7       1.00000  8       0.00000
 9        0.00000 10       1.00000 11       0.00000
      48
 1  1     1.0000   1  2    1.00000  1  3    1.00000  2  4    1.00000
 2  7     1.0000   2 10    1.00000  3  1    1.00000  3  8    1.00000
 3 11     1.0000   4  2    1.00000  4  5    1.00000  4 12    1.00000
 5  3     1.0000   5  6    1.00000  5  9    1.00000  6  4    1.00000
 6  5     1.0000   6  6    1.00000  7  7    1.00000  7  8    1.00000
 7  9     1.0000   8 10    1.00000  8 11    1.00000  8 12    1.00000
 9  2     1.0000   9  3    1.00000  9  5    1.00000  9  6    1.00000
10  7     1.0000  10  8    1.00000 10 10    1.00000 10 11    1.00000
11  1     1.0000  11  2    1.00000 11 11    1.00000 11 12    1.00000
12  4     1.0000  12  6    1.00000 12  7    1.00000 12  9    1.00000
13  4     1.0000  13  5    1.00000 13 10    1.00000 13 12    1.00000
14  1     1.0000  14  3    1.00000 14  8    1.00000 14  9    1.00000
      14
 1        1.0000   2       1.00000  3       1.00000  4       1.00000
 5        1.0000   6       1.00000  7       1.00000  8       1.00000
 9        1.0000  10       1.00000 11       1.00000 12       1.00000
13        1.0000  14       1.00000
      36
 1  1   -81.8000   1  2  -88.40000  1  3  -81.20000  1  4  -98.10000
 1  5    -6.6000   1  6  -37.40000  1  7  -92.10000  1  8   -6.60000
 1  9    -7.8000   1 10  -90.70000  1 11  -54.20000  1 12   -7.80000
 2  1   -14.2600   2  2  -18.70000  2  3   -9.44000  2  4  -13.1900
 2  5    -2.9200   2  6  -11.68000  2  7  -17.01000  2  8   -2.93000
 2  9    -4.6300   2 10  -16.33000  2 11  -11.68000  2 12   -4.63000
 3  1    -0.0000   3  2   -6.26000  3  3   -2.96000  3  4   -0.00000
 3  5    -4.9200   3  6   -2.46000  3  7   -6.26000  3  8   -4.92000
 3  9    -5.8100   3 10   -2.46000  3 11   -2.46000  3 12   -5.81000
```

```
NAME              SCENARIO 3 LAMBDA SET (.333,.333,.333)
     850          3        12         2       11      14          0        40
       6
  1   1     1.00000  1  2     1.00000  1  3    1.00000  2  4    1.00000
  2   7     1.00000  2 10     1.00000
      2
  1         1.00000  2        1.00000
      42
  1   1     1.00000  1  8     1.00000  1 11    1.00000  2  2    1.00000
  2   5     1.00000  2 12     1.00000  3  3    1.00000  3  6    1.00000
  3   9     1.00000  4  1     1.00000  4  2    1.00000  4  3    1.00000
  5   4     1.00000  5  5     1.00000  5  6    1.00000  6  7    1.00000
  6   8     1.00000  6  9     1.00000  7 10    1.00000  7 11    1.00000
  7  12     1.00000  8  1     1.00000  8  4   -1.00000  8  5   -1.00000
  8   6    -1.00000  8  8     1.00000  8 11    1.00000  9  3    1.00000
  9   6     1.00000  9  9     1.00000  9 10   -1.00000  9 11   -1.00000
  9  12    -1.00000 10  4     1.00000 10  7    1.00000 10 10    1.00000
 11   2     1.00000 11  5     1.00000 11  7   -1.00000 11  8   -1.00000
 11   9    -1.00000 11 12     1.00000
      11
  1         1.00000  2        1.00000  3       1.00000  4       1.00000
  5         1.00000  6        1.00000  7       1.00000  8       0.00000
  9         0.00000 10        1.00000 11       0.00000
      48
  1   1     1.0000   1  2     1.00000  1  3    1.00000  2  4    1.00000
  2   7     1.0000   2 10     1.00000  3  1    1.00000  3  8    1.00000
  3  11     1.0000   4  2     1.00000  4  5    1.00000  4 12    1.00000
  5   3     1.0000   5  6     1.00000  5  9    1.00000  6  4    1.00000
  6   5     1.0000   6  6     1.00000  7  7    1.00000  7  8    1.00000
  7   9     1.0000   8 10     1.00000  8 11    1.00000  8 12    1.00000
  9   2     1.0000   9  3     1.00000  9  5    1.00000  9  6    1.00000
 10   7     1.0000  10  8     1.00000 10 10    1.00000 10 11    1.00000
 11   1     1.0000  11  2     1.00000 11 11    1.00000 11 12    1.00000
 12   4     1.0000  12  6     1.00000 12  7    1.00000 12  9    1.00000
 13   4     1.0000  13  5     1.00000 13 10    1.00000 13 12    1.00000
 14   1     1.0000  14  3     1.00000 14  8    1.00000 14  9    1.00000
      14
  1         1.0000   2        1.00000  3       1.00000  4       1.00000
  5         1.0000   6        1.00000  7       1.00000  8       1.00000
  9         1.0000  10        1.00000 11       1.00000 12       1.00000
 13         1.0000  14        1.00000
      36
  1   1   -37.8000   1  2   -44.50000  1  3  -50.30000  1  4  -37.90000
  1   5    -6.6000   1  6   -10.30000  1  7  -42.40000  1  8   -6.60000
  1   9    -7.9000   1 10   -48.20000  1 11  -10.30000  1 12   -7.90000
  2   1    -3.5600   2  2    -4.62000  2  3   -6.12000  2  4   -4.36000
  2   5    -2.9300   2  6    -3.65000  2  7   -4.59000  2  8   -2.93000
  2   9    -3.9700   2 10    -6.46000  2 11   -3.67000  2 12   -4.02000
  3   1    -0.0000   3  2    -6.33000  3  3   -7.07000  3  4   -4.08000
  3   5    -4.9200   3  6    -7.67000  3  7   -8.64000  3  8   -4.92000
  3   9    -5.8800   3 10   -11.75000  3 11   -7.67000  3 12   -5.88000
```

```
NAME          SCENARIO 3 LAMBDA SET (.25,.375,.375)
     850        3       12        2       11     14         0       40
       6
  1  1     1.00000  1  2     1.00000  1  3    1.00000  2  4    1.00000
  2  7     1.00000  2 10     1.00000
      2
  1        1.00000  2        1.00000
      42
  1  1     1.00000  1  8     1.00000  1 11    1.00000  2  2    1.00000
  2  5     1.00000  2 12     1.00000  3  3    1.00000  3  6    1.00000
  3  9     1.00000  4  1     1.00000  4  2    1.00000  4  3    1.00000
  5  4     1.00000  5  5     1.00000  5  6    1.00000  6  7    1.00000
  6  8     1.00000  6  9     1.00000  7 10    1.00000  7 11    1.00000
  7 12     1.00000  8  1     1.00000  8  4   -1.00000  8  5   -1.00000
  8  6    -1.00000  3  8     1.00000  8 11    1.00000  9  3    1.00000
  9  6     1.00000  9  9     1.00000  9 10   -1.00000  9 11   -1.00000
  9 12    -1.00000 10  4     1.00000 10  7    1.00000 10 10    1.00000
 11  2     1.00000 11  5     1.00000 11  7   -1.00000 11  8   -1.00000
 11  9    -1.00000 11 12     1.00000
      11
  1        1.00000  2        1.00000  3       1.00000  4       1.00000
  5        1.00000  6        1.00000  7       1.00000  8       0.00000
  9        0.00000 10        1.00000 11       0.00000
      48
  1  1     1.0000   1  2     1.00000  1  3    1.00000  2  4    1.00000
  2  7     1.0000   2 10     1.00000  3  1    1.00000  3  8    1.00000
  3 11     1.0000   4  2     1.00000  4  5    1.00000  4 12    1.00000
  5  3     1.0000   5  6     1.00000  5  9    1.00000  6  4    1.00000
  6  5     1.0000   6  6     1.00000  7  7    1.00000  7  8    1.00000
  7  9     1.0000   8 10     1.00000  8 11    1.00000  8 12    1.00000
  9  2     1.0000   9  3     1.00000  9  5    1.00000  9  6    1.00000
 10  7     1.0000  10  8     1.00000 10 10    1.00000 10 11    1.00000
 11  1     1.0000  11  2     1.00000 11 11    1.00000 11 12    1.00000
 12  4     1.0000  12  6     1.00000 12  7    1.00000 12  9    1.00000
 13  4     1.0000  13  5     1.00000 13 10    1.00000 13 12    1.00000
 14  1     1.0000  14  3     1.00000 14  8    1.00000 14  9    1.00000
      14
  1        1.0000   2        1.00000  3       1.00000  4       1.00000
  5        1.0000   6        1.00000  7       1.00000  8       1.00000
  9        1.0000  10        1.00000 11       1.00000 12       1.00000
 13        1.0000  14        1.00000
      36
  1  1   -37.8000   1  2   -44.50000  1  3  -50.20000  1  4  -37.90000
  1  5    -6.6000   1  6   -10.30000  1  7  -42.40000  1  8   -6.60000
  1  9    -7.9000   1 10   -50.40000  1 11  -10.30000  1 12   -7.90000
  2  1    -3.5600   2  2    -4.62000  2  3   -6.98000  2  4   -4.36000
  2  5    -2.9300   2  6    -3.65000  2  7   -4.59000  2  8   -2.93000
  2  9    -3.9700   2 10    -6.88000  2 11   -3.57000  2 12   -4.02000
  3  1    -0.0000   3  2    -6.33000  3  3   -6.33000  3  4   -4.08000
  3  5    -4.9200   3  6    -7.67000  3  7   -8.64000  3  8   -4.92000
  3  9    -5.8800   3 10    -9.45000  3 11   -7.67000  3 12   -5.88000
```

```
NAME          SCENARIO 3 LAMBDA SET (.375,.25,.375)
     850         3        12         2         11        14           0        40
       6
  1  1      1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7      1.00000  2 10      1.00000
      2
  1         1.00000  2         1.00000
     42
  1  1      1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
  2  5      1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
  3  9      1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
  5  4      1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
  6  8      1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
  7 12      1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.00000
  8  6     -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.00000
  9  6      1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
  9 12     -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
 11  2      1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
 11  9     -1.00000 11 12      1.00000
     11
  1         1.00000  2         1.00000  3         1.00000  4         1.00000
  5         1.00000  6         1.00000  7         1.00000  8         0.00000
  9         0.00000 10         1.00000 11         0.00000
     48
  1  1      1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7      1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
  3 11      1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
  5  3      1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
  6  5      1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00000
  7  9      1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00000
  9  2      1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
 10  7      1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
 11  1      1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
 12  4      1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
 13  4      1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
 14  1      1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
     14
  1         1.0000   2         1.00000  3         1.00000  4         1.00000
  5         1.0000   6         1.00000  7         1.00000  8         1.00000
  9         1.0000  10         1.00000 11         1.00000 12         1.00000
 13         1.0000  14         1.00000
     36
  1  1    -37.8000   1  2    -44.50000  1  3    -50.20000  1  4    -37.90000
  1  5     -6.6000   1  6    -10.30000  1  7    -42.40000  1  8     -6.60000
  1  9     -7.9000   1 10    -50.30000  1 11    -10.30000  1 12     -7.90000
  2  1     -3.5600   2  2     -4.62000  2  3     -6.98000  2  4     -4.36000
  2  5     -2.9300   2  6     -3.65000  2  7     -4.59000  2  8     -2.93000
  2  9     -3.9700   2 10     -7.77000  2 11     -3.67000  2 12     -4.02000
  3  1     -0.0000   3  2     -6.33000  3  3     -6.33000  3  4     -4.08000
  3  5     -4.9200   3  6     -7.67000  3  7     -8.64000  3  8     -4.92000
  3  9     -5.8800   3 10    -8.640000  3 11     -7.67000  3 12     -5.88000
```

```
NAME          SCENARIO 3 LAMBDA SET (.375,.375,.25)
    850         3      12         2       11       14          0       40
      6
  1  1      1.00000  1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7      1.00000  2 10      1.00000
     2
  1         1.00000  2         1.00000
     42
  1  1      1.00000  1  8      1.00000  1 11      1.00000  2  2      1.00000
  2  5      1.00000  2 12      1.00000  3  3      1.00000  3  6      1.00000
  3  9      1.00000  4  1      1.00000  4  2      1.00000  4  3      1.00000
  5  4      1.00000  5  5      1.00000  5  6      1.00000  6  7      1.00000
  6  8      1.00000  6  9      1.00000  7 10      1.00000  7 11      1.00000
  7 12      1.00000  8  1      1.00000  8  4     -1.00000  8  5     -1.00000
  8  6     -1.00000  8  8      1.00000  8 11      1.00000  9  3      1.00000
  9  6      1.00000  9  9      1.00000  9 10     -1.00000  9 11     -1.00000
  9 12     -1.00000 10  4      1.00000 10  7      1.00000 10 10      1.00000
 11  2      1.00000 11  5      1.00000 11  7     -1.00000 11  8     -1.00000
 11  9     -1.00000 11 12      1.00000
     11
  1         1.00000  2         1.00000  3         1.00000  4         1.00000
  5         1.00000  6         1.00000  7         1.00000  8         0.00000
  9         0.00000 10         1.00000 11         0.00000
     48
  1  1      1.0000   1  2      1.00000  1  3      1.00000  2  4      1.00000
  2  7      1.0000   2 10      1.00000  3  1      1.00000  3  8      1.00000
  3 11      1.0000   4  2      1.00000  4  5      1.00000  4 12      1.00000
  5  3      1.0000   5  6      1.00000  5  9      1.00000  6  4      1.00000
  6  5      1.0000   6  6      1.00000  7  7      1.00000  7  8      1.00000
  7  9      1.0000   8 10      1.00000  8 11      1.00000  8 12      1.00000
  9  2      1.0000   9  3      1.00000  9  5      1.00000  9  6      1.00000
 10  7      1.0000  10  8      1.00000 10 10      1.00000 10 11      1.00000
 11  1      1.0000  11  2      1.00000 11 11      1.00000 11 12      1.00000
 12  4      1.0000  12  6      1.00000 12  7      1.00000 12  9      1.00000
 13  4      1.0000  13  5      1.00000 13 10      1.00000 13 12      1.00000
 14  1      1.0000  14  3      1.00000 14  8      1.00000 14  9      1.00000
     14
  1         1.0000   2         1.00000  3         1.00000  4         1.00000
  5         1.0000   6         1.00000  7         1.00000  8         1.00000
  9         1.0000  10         1.00000 11         1.00000 12         1.00000
 13         1.0000  14         1.00000
     36
  1  1    -37.8000   1  2    -40.20000  1  3    -50.30000  1  4    -37.80000
  1  5     -6.6000   1  6    -10.30000  1  7    -40.30000  1  8     -6.60000
  1  9     -7.9000   1 10    -48.20000  1 11    -10.30000  1 12     -7.90000
  2  1     -3.5600   2  2     -3.65000  2  3     -6.11000  2  4     -3.45000
  2  5     -2.9300   2  6     -3.65000  2  7     -3.66000  2  8     -2.93000
  2  9     -3.9700   2 10     -6.46000  2 11     -3.67000  2 12     -4.02000
  3  1     -0.0000   3  2    -12.21000  3  3     -7.07000  3  4     -5.21000
  3  5     -4.9200   3  6     -7.67000  3  7    -12.29000  3  8     -4.92000
  3  9     -5.8800   3 10    -11.75000  3 11     -7.67000  3 12     -5.88000
```

```
NAME          SCENARIO 3 LAMBDA SET (.5,.25,.25)
     850          3        12          2       11       14          0        40
       6
  1   1     1.00000   1   2     1.00000   1   3     1.00000   2   4     1.00000
  2   7     1.00000   2  10     1.00000
       2
  1         1.00000   2         1.00000
      42
  1   1     1.00000   1   8     1.00000   1  11     1.00000   2   2     1.00000
  2   5     1.00000   2  12     1.00000   3   3     1.00000   3   6     1.00000
  3   9     1.00000   4   1     1.00000   4   2     1.00000   4   3     1.00000
  5   4     1.00000   5   5     1.00000   5   6     1.00000   6   7     1.00000
  6   8     1.00000   6   9     1.00000   7  10     1.00000   7  11     1.00000
  7  12     1.00000   8   1     1.00000   8   4    -1.00000   8   5    -1.00000
  8   6    -1.00000   8   8     1.00000   8  11     1.00000   9   3     1.00000
  9   6     1.00000   9   9     1.00000   9  10    -1.00000   9  11    -1.00000
  9  12    -1.00000  10   4     1.00000  10   7     1.00000  10  10     1.00000
 11   2     1.00000  11   5     1.00000  11   7    -1.00000  11   8    -1.00000
 11   9    -1.00000  11  12     1.00000
      11
  1         1.00000   2         1.00000   3         1.00000   4         1.00000
  5         1.00000   6         1.00000   7         1.00000   8         0.00000
  9         0.00000  10         1.00000  11         0.00000
      48
  1   1     1.0000    1   2     1.00000   1   3     1.00000   2   4     1.00000
  2   7     1.0000    2  10     1.00000   3   1     1.00000   3   8     1.00000
  3  11     1.0000    4   2     1.00000   4   5     1.00000   4  12     1.00000
  5   3     1.0000    5   6     1.00000   5   9     1.00000   6   4     1.00000
  6   5     1.0000    6   6     1.00000   7   7     1.00000   7   8     1.00000
  7   9     1.0000    8  10     1.00000   8  11     1.00000   8  12     1.00000
  9   2     1.0000    9   3     1.00000   9   5     1.00000   9   6     1.00000
 10   7     1.0000   10   8     1.00000  10  10     1.00000  10  11     1.00000
 11   1     1.0000   11   2     1.00000  11  11     1.00000  11  12     1.00000
 12   4     1.0000   12   6     1.00000  12   7     1.00000  12   9     1.00000
 13   4     1.0000   13   5     1.00000  13  10     1.00000  13  12     1.00000
 14   1     1.0000   14   3     1.00000  14   8     1.00000  14   9     1.00000
      14
  1         1.0000    2         1.00000   3         1.00000   4         1.00000
  5         1.0000    6         1.00000   7         1.00000   8         1.00000
  9         1.0000   10         1.00000  11         1.00000  12         1.00000
 13         1.0000   14         1.00000
      36
  1   1   -37.8000    1   2   -40.30000   1   3   -50.20000   1   4   -37.90000
  1   5    -6.6000    1   6   -10.30000   1   7   -40.40000   1   8    -6.60000
  1   9    -7.9000    1  10   -40.40000   1  11   -10.30000   1  12    -7.90000
  2   1    -3.5600    2   2    -4.86000   2   3    -6.97000   2   4    -4.36000
  2   5    -2.9300    2   6    -3.65000   2   7    -4.86000   2   8    -2.93000
  2   9    -3.9700    2  10    -6.46000   2  11    -3.67000   2  12    -4.02000
  3   1    -0.0000    3   2   -10.72000   3   3    -6.33000   3   4   -10.61000
  3   5    -4.9200    3   6    -7.67000   3   7   -10.80000   3   8    -4.08000
  3   9    -5.8800    3  10   -11.75000   3  11    -7.67000   3  12    -5.88000
```

```
NAME            SCENARIO 3 LAMBDA SET (.25,.5,.25)
     850        3        12        2        11      14        0       40
       6
  1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.00000  2 10     1.00000
       2
  1        1.00000  2        1.00000
      42
  1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
  2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
  3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
  5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
  6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
  7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
  8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
  9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
  9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
 11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
 11  9    -1.00000 11 12     1.00000
      11
  1        1.00000  2        1.00000  3        1.00000  4        1.00000
  5        1.00000  6        1.00000  7        1.00000  8        0.00000
  9        0.00000 10        1.00000 11        0.00000
      48
  1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
  3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
  5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
  6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
  7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
  9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
 10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
 11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
 12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
 13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
 14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
      14
  1        1.0000   2        1.00000  3        1.00000  4        1.00000
  5        1.0000   6        1.00000  7        1.00000  8        1.00000
  9        1.0000  10        1.00000 11        1.00000 12        1.00000
 13        1.0000  14        1.00000
      36
  1  1   -37.8000   1  2   -40.20000  1  3   -50.30000  1  4   -37.80000
  1  5    -6.6000   1  6   -10.30000  1  7   -40.30000  1  8    -6.60000
  1  9    -7.9000   1 10   -48.20000  1 11   -10.30000  1 12    -7.90000
  2  1    -3.5600   2  2    -3.65000  2  3    -6.11000  2  4    -3.45000
  2  5    -2.9300   2  6    -3.65000  2  7    -3.66000  2  8    -2.93000
  2  9    -3.9700   2 10    -6.46000  2 11    -3.67000  2 12    -4.02000
  3  1    -0.0000   3  2   -12.21000  3  3    -7.07000  3  4    -5.21000
  3  5    -4.9200   3  6    -7.67000  3  7   -12.29000  3  8    -4.92000
  3  9    -5.8800   3 10   -11.75000  3 11    -7.67000  3 12    -5.88000
```

```
NAME          SCENARIO 3 LAMBDA SET (.25,.25,.5)
     850         3       12        2       11       14        0       40
       6
  1  1     1.00000  1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.00000  2 10     1.00000
      2
  1        1.00000  2        1.00000
      42
  1  1     1.00000  1  8     1.00000  1 11     1.00000  2  2     1.00000
  2  5     1.00000  2 12     1.00000  3  3     1.00000  3  6     1.00000
  3  9     1.00000  4  1     1.00000  4  2     1.00000  4  3     1.00000
  5  4     1.00000  5  5     1.00000  5  6     1.00000  6  7     1.00000
  6  8     1.00000  6  9     1.00000  7 10     1.00000  7 11     1.00000
  7 12     1.00000  8  1     1.00000  8  4    -1.00000  8  5    -1.00000
  8  6    -1.00000  8  8     1.00000  8 11     1.00000  9  3     1.00000
  9  6     1.00000  9  9     1.00000  9 10    -1.00000  9 11    -1.00000
  9 12    -1.00000 10  4     1.00000 10  7     1.00000 10 10     1.00000
 11  2     1.00000 11  5     1.00000 11  7    -1.00000 11  8    -1.00000
 11  9    -1.00000 11 12     1.00000
      11
  1        1.00000  2        1.00000  3        1.00000  4        1.00000
  5        1.00000  6        1.00000  7        1.00000  8        0.00000
  9        0.00000 10        1.00000 11        0.00000
      48
  1  1     1.0000   1  2     1.00000  1  3     1.00000  2  4     1.00000
  2  7     1.0000   2 10     1.00000  3  1     1.00000  3  8     1.00000
  3 11     1.0000   4  2     1.00000  4  5     1.00000  4 12     1.00000
  5  3     1.0000   5  6     1.00000  5  9     1.00000  6  4     1.00000
  6  5     1.0000   6  6     1.00000  7  7     1.00000  7  8     1.00000
  7  9     1.0000   8 10     1.00000  8 11     1.00000  8 12     1.00000
  9  2     1.0000   9  3     1.00000  9  5     1.00000  9  6     1.00000
 10  7     1.0000  10  8     1.00000 10 10     1.00000 10 11     1.00000
 11  1     1.0000  11  2     1.00000 11 11     1.00000 11 12     1.00000
 12  4     1.0000  12  6     1.00000 12  7     1.00000 12  9     1.00000
 13  4     1.0000  13  5     1.00000 13 10     1.00000 13 12     1.00000
 14  1     1.0000  14  3     1.00000 14  8     1.00000 14  9     1.00000
      14
  1        1.0000   2        1.00000  3        1.00000  4        1.00000
  5        1.0000   6        1.00000  7        1.00000  8        1.00000
  9        1.0000  10        1.00000 11        1.00000 12        1.00000
 13        1.0000  14        1.00000
      36
  1  1   -37.8000   1  2   -44.50000  1  3   -50.20000  1  4   -37.90000
  1  5    -6.6000   1  6   -10.30000  1  7   -42.40000  1  8    -6.60000
  1  9    -7.9000   1 10   -60.60000  1 11   -10.30000  1 12    -7.90000
  2  1    -3.5600   2  2    -4.62000  2  3    -6.98000  2  4    -4.36000
  2  5    -2.9300   2  6    -3.65000  2  7    -4.59000  2  8    -2.93000
  2  9    -3.9700   2 10    -9.34000  2 11    -3.67000  2 12    -4.02000
  3  1    -0.0000   3  2    -6.33000  3  3    -6.33000  3  4   -10.61000
  3  5    -4.9200   3  6    -7.67000  3  7    -8.64000  3  8    -4.08000
  3  9    -5.8800   3 10    -2.46000  3 11    -7.67000  3 12    -5.88000
```

BIBLIOGRAPHY

1. Air Force Electronic Warfare Center, Kelly AFB TX. The Improved Many-on-Many description handout received from MAJ Thomas Sterling, USAF on 28 July 1990.

2. Air Force Regulation 80 - 38. "Management of the Air Force Systems Survivability Program," August 1982.

3. Ball, Robert E. The Fundamentals of Aircraft Combat Survivability Analysis and Design. American Institute for Aeronautics and Astronautics Education Series, 1985.

4. Bartholdi, John J. and Loren K. Platzman. "Heuristics Based on Spacefilling Curves for Combinatorial Problems in Euclidean Space", Management Science, Volume 34, Number 3: 291 - 305 (March 1988).

5. Carraway, Robert L. "Generalized Dynamic Programming for Multicriteria Optimization", European Journal Operations Research, Number 1: 93 - 104 (January 1990).

6. Chan, Yupo. Integrated Location-and-Routing Models - Part II, School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB, OH, January 1990.

7. Chan, Yupo and William Rowell. Integrated Location-and-Routing Models - Part I, School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB, OH, January 1990.

8. Department of the Army. Operations. FM 100-5. Washington: HQ DA, June 1987.

9. Gilman, Robert John. Survivability Considerations During Aircraft Conceptual Design. Thesis: Naval Post Graduate School, Monterey, CA, March 1986.

10. Goodman, S. E. and S. T. Hedeetniemi. Introduction to the Design and Analysis of Algorithms. McGraw Hill Book Company, 1977.

11. Hartman, James K. Lecture Notes in High Resolution Combat Modeling, 1985.

12. Johnson, Ruben Phd. Operations Research. Personal interview. Air Force Institute of Technology, Wright-Patterson AFB OH, August 1990.

13. Klincewicz, John J. and Hanan Luss. "Fleet Size Planning When Outside Carrier Services Are Available," Transportation Science, Volume 24, Number 3: 169 -182 (August 1990).

14. Minoux, M. Mathematical Programming. Theory and Algorithms. John Wiley and Sons Ltd., 1986.

15. Oldham, Loel E. "Automated Optimized Strike Planning," Electronic Warfare Center, Kelly AFB TX.

16. Oliver, J. Telephone interview. Studies and Analysis, Electronic Warfare Center, Kelly AFB TX, 5 February, 1991.

17. Steuer, Ralph E. ADBASE Operating Manual Parts I and II. Department of Management Science and Information Technology, Brooks Hall, Athens GA., September 1990.

18. Sterling, Thomas MAJ USAF. Personal interview. Studies and Analysis, Electronic Warfare Center, Kelly AFB TX, 28 July 1990.

19. Tactical Sensor Planner Users/Operations Manual, Volume I, Version 4.00. Fox Technology Incorporated, Dallas, TX.

20. Users/Operations Manual for the Improved Many-On-Many (IMOM), Version 4.4 (Beta Source). Air Force Electronic Warfare Center, Kelly AFB, TX., June 1990.

21. Yu, Po-Lung. Multiple-Criteria Decision Making. New York and London: Plenum Press, 1985.

VITA

Captain Ernst Kangle Isensee was born in Chicago, Illinois on June 24, 1958. In July 1978 he entered the United States Military Academy at West Point, New York. He was commissioned as an Infantry Officer in May 1982. After attending the Infantry Officers Basic Course at Fort Benning, Georgia, Captain Isensee was assigned to C (airborne) Company 6/327 Infantry Regiment, Fort Waiwright Alaska. While at Fort Wainwright, Captain Isensee served as an airborne rifle platoon leader and company executive officer. He also served as the 6/327 Infantry Regiment support and transportation officer. After attending the Infantry Officers Advanced course in 1986 at Fort Benning, Georgia, Captain Isensee was assigned to the 1/505 Parachute Infantry Regiment, 82nd Airborne Division, Fort Bragg, North Carolina. While assigned to the 1/505 P.I.R. Captain Isensee commanded the Combat Support Company, D Company and Headquarters and Headquarters Company. He also served as the chief tactics instructor in the division Airborne Leaders Course. Captain Isensee's awards and decorations include the ranger tab, pathfinder badge, expert infantry badge, master parachutist wings and ARCOM with oak leaf cluster.